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PINOCCHIO
A COMPUTER PROGRAM FOR CELL REACTIVITY CALCULATIONS

by

L. AMYOT, G. CASINI, R. CUNIBERTI and C. DAOLIO

1969

ORGEL Program

Joint Nuclear Research Center
Ispra Establishment - Italy

Reactor Physics Department
Reactor Theory and Analysis

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KEYWORDS

PROGRAMMING
P-CODES
EIGENVALUES
REACTOR LATTICES
REACTIVITY
TRANSPORT THEORY
INTEGRAL EQUATIONS
FUEL RODS
FUEL ELEMENT CLUSTERS
IBM 360

TABLE OF CONTENTS

Part I

THEORY

Introduction (*)

The specific requirements of a reactor project will usually be met by the development of correlation techniques or phenomenological descriptions which may be relied upon to provide an adequate representation of lattice cell physics in a narrow range of composition and geometry. Examples of such methods are the codes CAROLINE[1] and PLUTHARCO[2] written at Ispra in the framework of the ORGEL project. Of course, care must be exercised when the design studies stray away from the conditions to which these simple recipes are better suited; in the analysis of differential effects due, for instance, to burnup or temperature, a frequent practice is to resort to methods based on more detailed physical models. Historically, this was the main incentive for the development of the code PINOCCHIO.

A further stimulus to provide comprehensive schemes of lattice cell calculations is found in the desire to improve the precision and reliability of the theoretical predictions by searching for patterns in the discrepancies between computations and measurements. The possibility of investigating many types of reactors - e.g. graphite, light water and heavy water - is then highly desirable since it will provide a broad range of neutron spectra and isotopic compositions, stressing alternately various phases of the neutron cycle. Although practical necessities have kept this second point in the background, an effort has been made in the writing of PINOCCHIO to maintain as much generality as was compatible with more pressing requirements. The logical evolution of a code such as PINOCCHIO should produce a relatively inexpensive and versatile computing tool requiring as input only the raw geome-

(*) Manuscript received on 20 October 1968.

trical data and nuclear cross sections of the material composing the lattice.

While the original version[3] was based on the four-factor representation of the neutron cycle, the code has since undergone several transformations embodying various improvements in the physical model, adding generality to the types of systems which may be treated and increasing the potentialities, e.g. through the adjunction of a burnup subroutine. In its present state, PINOCCHIO will solve the eigenvalue problem and perform a complete reactivity-time calculations for an infinite lattice fueled with single rods or cluster type elements. The method is based throughout on the use of first collision probabilities in a multigroup energy structure. The geometries specifically provided for in the current version and the energy group structure are described respectively in Table 1 and 2.

Table 1

Fuel element geometries included in PINOCCHIO

No.	Description
1	Single rod without housing tube
2	Single rod with housing tube
3	4-rod cluster without housing tube
4	4-rod cluster with housing tube
5	4-rod cluster with pressure tubes around each pin
6	7-rod cluster without housing tube
7	7-rod cluster with housing tube
8	19-rod hexagonal cluster without housing tube
9	19-rod circular cluster without housing tube
10	19-rod hexagonal cluster with housing tube
11	19-rod circular cluster with housing tube
12	37-rod cluster without housing tube
13	37-rod cluster with housing tube

Table 2

Energy group structure

(1)Spatial calculations	Group No.	Energy interval, eV
	1	$1.49 \times 10^7 - 1.35 \times 10^6$
	2	$1.35 \times 10^6 - 1.11 \times 10^5$
	3	$1.11 \times 10^5 - 3.18 \times 10^4$
	4	$3.18 \times 10^4 - 961$
	5	961 - 130
	6	130 - 47.8
	7	47.8 - 29.0
	8	29.0 - 10.7
	9	10.7 - 2.38
	10	2.38 - 0

(2) Thermal spectrum calculations	Group No.	Energy interval eV	Group No.	Energy interval eV
	1	2.200 - 1.500	16	0.414 - 0.350
	2	1.500 - 1.300	17	0.350 - 0.310
	3	1.300 - 1.200	18	0.310 - 0.270
	4	1.200 - 1.150	19	0.270 - 0.220
	5	1.150 - 1.110	20	0.220 - 0.160
	6	1.110 - 1.090	21	0.160 - 0.100
	7	1.090 - 1.070	22	0.100 - 0.085
	8	1.070 - 1.050	23	0.085 - 0.060
	9	1.050 - 1.025	24	0.060 - 0.040
	10	1.025 - 1.000	25	0.040 - 0.030
	11	1.000 - 0.970	26	0.030 - 0.025
	12	0.970 - 0.910	27	0.025 - 0.015
	13	0.910 - 0.700	28	0.015 - 0.010
	14	0.700 - 0.500	29	0.010 - 0.005
	15	0.500 - 0.414	30	0.005 - 0.0

Cell cross section data, except for the resonance integrals which will be dealt with in more detail below, are taken from the GAM-II[4] library for the epithermal region and the GATHER-II[5] library for the thermal range. However, the 2200 m/s constants for U-233, U-235, Pu-239 and Pu-241 are extracted from the 1965 study of Westcott et al.[6]. To construct the PINOCCHIO library in the group structure described in Table 2, energy condensation was effected with the help of GGC-II[4] for an ideal homogeneous system constituted of heavy water and natural uranium.

The code was first written in FORTRAN-II for the IBM-7090 but has recently been translated for use on the IBM 360. A typical eigenvalue problem requires of the order of 1-2 m.

The main features of the physical model are given in the following paragraphs. A brief description of the code completes the report. Comparisons with experiments will be given in a forthcoming publication.

1. Eigenvalue Problem

Two sets of criticality equations are used in PINOCCHIO according to whether the fast fission events are considered as forming an integral part of the average neutron lifecycle or a side process. The first viewpoint is the more frequently adopted in reactor calculations. The second representation offers the advantage of being easily reducible to the classical four-factor formula (at least, in the absence of epithermal fissions). While the convenience of the latter picture is taken advantage of in the actual establisment of the neutron balance, it was thought advisable to formulate the output of PINOCCHIO in the more familiar frame of the former outlook.

Of course, at criticality, the properties of a chain-reacting system are univocally defined. The material buck-

lings obtained from all possible expressions of the criticality equations are thus identically equal; assuming that the buckling remains constant as a function of energy, we may write:

$$\sum_m \alpha_{mn} \phi_m = B^2 \phi_n \qquad (1)$$

where

$$\alpha_{mn} = D_n^{-1} c_{mn} \Sigma_m \qquad (m \neq n)$$

$$\alpha_{nn} = D_n^{-1} \left[c_{nn} \Sigma_n - \tilde{\Sigma}_{rn} \right]$$

$c_{m,n}$ is the number of neutrons appearing in group n at each collision in group m; Σ_n is the cell-averaged collision cross section in group n ; $\tilde{\Sigma}_{rn}$ is the cell-averaged removal cross section in group n ; D_n is the cell-averaged diffusion coefficient in group n.

When all reaction rates are referred to one neutron leaving (or produced in) the system, the value of k-eff is given by

$$k_{eff} = \frac{\sum_m (\nu \Sigma_f)_m \phi_m}{\sum_n \left[\Sigma_{a,n} + D_n B^2 \right] \phi_n} \qquad (2)$$

When the reference is to one neutron produced by fissions taking place below a given energy limit, we have on the other hand

$$k'_{eff} = \frac{\sum_{m=F}^{N} (\nu\Sigma_f)_m \phi_m}{\sum_{m=1}^{N} \left[\Sigma_{a,m} + D_m B^2\right]\phi_m - \sum_{m=1}^{F} (\nu\Sigma_f)_m \phi_m} = \frac{\sum_{m=F}^{N} (\nu\Sigma_f)_m \phi_m + k'_{eff} \sum_{m=1}^{F} (\nu\Sigma_f)_m \phi_m}{\sum_{m=1}^{N} \left[\Sigma_{a,m} + D_m B^2\right]\phi_m} \qquad (3)$$

where F is the number of fast groups. Comparing equations (2) and (3) we find

$$k_{eff} = k'_{eff} + (1 - k'_{eff}) \frac{\sum_{m=1}^{F} (\nu\Sigma_f)_m \phi_m}{\sum_{m=1}^{F} (\Sigma_{R,m} + D_m B^2)\phi_m} \qquad (4)$$

Since k'-eff is normally close to unity, the second term on the right hand side will usually be small and, in PINOCCHIO, only the first definition of k-eff is retained.

The expressions for the infinite multiplication factor corresponding to both points of view are derived by setting the buckling equal to zero in equations (2) and (3), and their relationship is described by introducing the same modification in equation (4). It will immediately appear that, in this case the choice of the definition is not trivial and significantly different values will be obtained according to the preferred representation of the neutron cycle. Both results are printed in the output of PINOCCHIO.

1.1 The fast effect

The traditional division of the energy scale into fast, epithermal and thermal ranges must always involve some element of arbitrariness in view of the complexity and the interrelations of the phenomena taking place in the system at all energies. One could , in principle, simply write down the energy-dependent Boltzman equation in a suitably general form and apply it with-

out modification to the particular geometrical situation under study. In practice, however, it is usually found adequate and economical to resort to different conveniently simplified treatments in different energy regions.

In thermal assemblies with low fuel enrichments, the predominant event at high energy is U-238 fission but of comparable importance for the definition of the fast range is the fact that the virgin neutron spectrum resulting from all fissions vanishes into insignificance outside a not very wide band of energy where it produces strongly localized sources. Thus, at lower energies, even complex-shaped fuel elements may reasonably be represented in a simpler geometry of concentric cylindrical annuli but, in the vicinity of the Mev-range, the rod geometry must often be more closely approximated especially with gas-cooled elements.

In PINOCCHIO, the lower threshold of the fast region is chosen as 0.1 Mev. More than 98.4% of the fission spectrum is above this point. Furthermore, inelastic scattering and resonance capture in uranium-238 both become negligible in the vicinity of that energy which thus appears as a fairly natural limit.

The neutron balance equation in the high energy region may be written for each of the p fast groups as

$$\Sigma_{j,m}\phi_{j,m}V_j = \sum_{m=1}^{p}\sum_i \left\{\Sigma_{i,m}\, g_{i,m\to m}\,\phi_{i,m} + q_{i,m}\right\} V_i P_{ij,m} \qquad (1<m\leq p)$$

where the transfer coefficient $g_{i,m\to n}$ is given by

$$q_{i,m\to m} = \frac{\Sigma^{el}_{i,m\to m} + \Sigma^{inel}_{i,m\to m} + 2\,\Sigma^{(m,2m)}_{i,m\to m} + (\nu\Sigma_f)_{i,m\to m}}{\Sigma_{i,m}}$$

and the source density $q_{i,n}$ by

$$\sum_{m=1}^{p}\sum_{j}\left[q_{j,m}V_j\right] = \sum_{m=p+1}^{p+q+r}\sum_{m=1}^{p}\sum_{j}\left[(\nu\Sigma_f)_{j,m\to m}\,\phi_{j,m}\,V_j\right] = 1$$

The indices i,j refer to regions; the indices m,n to energy groups. The entire energy range from zero to infinity is supposed to be divided into p fast groups, q epithermal and r thermal groups. The equation for the sources $q_{i,n}$ expresses the conditions of normalization for the fluxes in every group and region, as stated above.

A preliminary study (8) has shown that, even with an hydrogeneous coolant, the energy distribution of neutrons lying above the fission threshold of U-238 was, in the channel, very nearly that of the U-235 fission spectrum. While this was not true for subthreshold neutrons, the effect of variations in the lower energy spectrum on the value of the fast multiplication factor was found to be small, the order of magnitude being roughly the same as the error introduced by the uncertainty in the capture cross sections of U-238. In the light of these results, the use of a two-group structure in the calculation of the fast effect seems to be justified.

Due to the marked heterogeneity of the fast source distribution, it was thought advisable to provide a rather detailed representation of the cluster geometry for the evaluation of the spatial behaviour. At the same time, in view of the long mean free path of fast neutrons in all materials, various approximate techniques may be used to determine the collision probabilities[9]. In PINOCCHIO the cross sections of all mate-

rials lying between given source and target pins are homogenized, before proceeding to the calculation of the pin-to-pin collision probabilities for fast neutrons.

The fast neutron multiplication factor is defined as the number of neutrons slowing down past the lower limit (0.1 Mev) of the high energy region per neutron produced in thermal and epithermal fission. Thus, in the case of p fast groups

$$\varepsilon = \sum_{m=1}^{p} \sum_{m=p+1}^{p+q+r} \sum_{i} \left[g_{i,m \to m} \Sigma_{i,m} \phi_{i,m} V_i \right].$$

Back-scattering from the moderator and cell-to-cell interaction are implicity taken into account.

1.2 Epithermal events

1.2.1 Flux calculation

The intermediate energy range extends, in PINOCCHIO, from 0.1 Mev down to 2.38 eV. Formally, the neutron balance equations are quite similar to the relations pertaining to the high energy regions. However, the transfer coefficients $g_{i,m \to n}$ no longer include (n, 2 n) nor virgin fission neutron contributions, and the source densities are now given by

$$q_{j,m} = \sum_{m=1}^{p} \left[\Sigma_{j,m} g_{j,m \to m} \phi_{j,m} \right]$$

Thus, we have, in each of the q epithermal groups,

$$\Sigma_{j,m} \phi_{j,m} V_j = \sum_{m=p+1}^{m} \sum_{i} \left[\Sigma_{i,m} g_{i,m \to m} \phi_{i,m} + q_{i,m} \right] V_i P_{i j,m} \quad (p < m \leq p+q)$$

The probability p that a neutron will escape absorption while slowing down through the intermediate energy region is simply expressed as

$$p = \frac{\sum_{m=1}^{p+q} \sum_{m=p+q+1}^{p+q+r} \sum_{i} \left[\Sigma_{i,m} g_{i,m+m} \phi_{i,m} V_i \right]}{\sum_{m=1}^{p} \sum_{m=p+1}^{p+q+r} \sum_{i} \left[\Sigma_{i,m} g_{i,m+m} \phi_{i,m} V_i \right]}$$

The denominator is seen to be exactly equal to ϵ as defined above. The numerator, completely analogous in form, represents the total number of neutrons slowing down into the thermal range

An epithermal multiplication factor may also be defined as

$$(\nu/\eta)_{epi} = \frac{\sum_{m=p+1}^{p+q} \sum_{i} \left[(\nu\Sigma_f)_{i,m} \phi_{i,m} V_i \right]}{\sum_{m=p+1}^{p+q} \sum_{i} \left[(\Sigma_a)_{i,m} \phi_{i,m} V_i \right]}$$

In the present version of PINOCCHIO, the intermediate range is divided into seven groups. The lattice cell is represented as a network of concentric circular annuli and the calculation of the collision probabilities follows the method of Bonalumi[10] The neutrons are assumed to be reflected isotropically at the cell boundary. The source distribution is evaluated by performing a flux calculation in the same geometry also for the two fast groups. normalizing for cluster problems the value of ϵ to the result obtained in the more exact geometry, as described in section 1.1.

1.2.2 Input data for flux calculations

A study of the influence of the lattice pitch on the group-averaged microscopic cross sections entering as input data has

been carried out for a typical heavy water core. This influence being found to be negligible, a single set of nuclear data (except for resonance cross sections) has been supplied for all materials in the form of a library.

A preliminary analysis [11] has shown that seven energy groups in the range between 0.1 Mev and 2.3 eV are enough to reproduce the correct absorption in U-238. Since absorption in other materials is thought to be of secondary importance with the low enrichments for which the code is intended, no provision has been made in the present version to refine the energy structure.

The resonance integrals were first calculated for the different groups by Nordheim's method, using the ZUT and TUZ programmes[12]. However, to avoid the necessity of including in PINOCCHIO the ZUT and TUZ programmes which require a relatively large amount of machine-time (5-10 minutes) an anlysis was carried out in the hope of correlating the Nordheim results with simplified formulae. In the Nordheim approach to resonance integral calculation, there are two parameters which enter as input data to characterize the fuel element geometry: the fuel radius and the Dancoff coefficient. The possibility of collecting them into a single variable, the effective surface, was investigated.

A best fit of the uranium-238 resonance integral in the form $A + B\sqrt{\frac{Seff}{M}}$ was performed for five values of $\frac{Seff}{M}$ ranging from 0.2 (0.1) to 0.6. Every point was calculated with ZUT and TUZ, assuming, as suggested by Levine[13], that

$$\frac{S_{eff}}{M} = \frac{1-C}{1+0.1C} \cdot \frac{2}{r\rho}$$

Table 3

U-238 resonance integral constants at 20°C

Group	Metal			Oxide			Carbide		
	A	B	Standard error	A	B	Standard error	A	B	Standard error
4	1.7474	1.1519	0.00768	1.7446	1.2327	0.00740	1.6685	1.2742	0.00737
5	0.4783	3.0640	0.01947	0.8454	2.8717	0.02689	0.7342	2.8563	0.02526
6	0.2678	2.5660	0.00675	0.5905	2.3638	0.01846	0.5007	2.3501	0.01518
7	0.0778	3.6651	0.00940	0.4315	3.4920	0.00477	0.3424	3.4411	0.00340
9	-.0208	4.5901	0.00704	0.3655	4.5020	0.01549	0.2741	4.3871	0.01338
9	-.1469	10.1605	0.02168	0.2923	10.5484	0.02057	0.2212	10.1278	0.02058
Total	2.8156	25.1976	0.02957	4.6819	25.0106	0.07794	4.1531	24.4367	0.06803

where ρ is the fuel density; r, the rod radius; C, the Dancoff coefficient. Three sets of calculations were run for C=0.0, 0.4 and 0.6 respectively. The best fitted values of A and B for the different energy groups, together with the standard deviations are given in Table 3 for the metal, carbide and oxide at 20°C.

As can be seen, the accuracy of the predictions appears quite satisfactory. The quoted values of A and B, have been incorporated in PINOCCHIO, thus replacing the complete ZUT and TUZ calculations. The correlation has now been extended to the range of fuel temperature from 20°C to 1600°C.

For the highest epithermal group (between 32 KeV and 0.1 MeV)a mean U-238 absorption cross section of 0.34b was adopted. This value was obtained by averaging the U-235 - $\sigma_{n,\gamma}$ as given in BNL-235 on typical heavy water lattice spectra calculated by the Monte Carlo techniques.

Exactly the same procedure was used to determine the epithermal constants of Th-232. In the case of uranium-235, a slightly more complicated correlation was developed[14] for both the fission and absorption resonance integrals:

$$I^{-2} = a_0 + a_1 \vartheta + a_2 \vartheta^2$$

The variable ϑ which plays a part similar to that of the effective surface in the case of the fertile isotopes is given by:

$$\vartheta = \sum_i \lambda_i \sigma_{p,i} \quad \tau_{tot} \qquad (5)$$

where $\sigma_{p,i}$ is the potential scattering cross section per uranium atom for the i^{th} isotope in the fuel lump: λ_i is the so-called slowing down efficiency, i.e. the average probability for a neutron scattered by nuclide i to be slowed down to energies below resonance; σ_{tot} is the contribution to the effective potential cross section due to fuel heterogeneity, i.e.:

$$\sigma_{fuel} = \frac{M_f \cdot E}{\mu A} \cdot \frac{S_{fuel}}{M}$$

M_f being the fuel molecular weight and E the enrichment. Equ. (5) is thus a form of equivalence theorem.

The resonance integral constants a_0, a_1, a_2 were derived, here again, by fitting the results of ZUT and TUZ over a range of Dancoff coefficients and rod radii. Two sets resulted, one for low enrichments (0-8%), the second one for high enrichments (8-100%).

For the time being, correlated values of U-235 resonance constants have been introduced only in the lower three epithermal groups. Although the standard deviations are larger than for the fertile isotopes, the results are judged to be good enough to justify an extension of the technique to higher energy groups and other fissile nuclides.

The resonance cross sections in a given group are simply defined as equal to the resonance integrals in the group divided by the lethargy width of the group . A much more refined method of calculation also based on the solution of the Boltzmann equation by the collision probability technique but with a very large number of group is presently being written to provide a theoretical check on the PINOCCHIO model for resonance absorption. This code, called PETARD[23], does not use the concept of resonance integrals and Dancoff factor: the basic cross sections are used throughout and the channel geometry is very closely represented.

1.2.3 Dancoff factor calculation

As an adjunct to PINOCCHIO, a code to evaluate the Dancoff factor in clusters and lattices has been established. The following assumptions are adopted in the calculation:
a) the fuel pencils are inserted in an infinite homogeneous moderator. This is not true, for instance, in an ORGEL-type re-

actor where the organic coolant acts as a secondary moderator inside the fuel clusters. However, the assumption is still valid if the source density is approximately constant throughout the cluster and not too different from the source density in the primary moderator.

b) The fuel is black to neutrons of the energy considered. This approximation becomes progressively poorer at higher energies.

c) A single collision with a moderator atom removes the neutron from the energy region considered. This will be true when the resonances are narrow enough or the moderating nuclide sufficiently light.

The calculation proceeds as follow:
- first, partial Dancoff coefficients C_{ij}, i.e. the reduction in flux at the surface of pins i due to the presence of pins j, are evaluated by following the method pioneered by Carlvik and Pershagen[15];
- then, the total Dancoff factor for the fuel cluster (or lattice) is obtained by summing the C_{ij} over all pins i and j. The calculation takes into account in a rigorous way the geometry of the cluster (or lattice) and of the cladding sheath.

1.3 Thermal multiplication factor

1.3.1 Spectrum calculations

The fundamental assumption in the analysis of the thermal effects is the separability of the spectral and spatial aspects of the problem. More precisely, the spectral effects are obtained in a rough geometrical representation of the fuel cell

through a 30 group THERMOS calculation[13]. A previous study has shown that the variation of the neutron spectrum across a unit cell is sufficiently well approximated by taking five annular regions: three in the fuel, one in the moderator, one in an intermediate region. The main advantage of this procedure is that it is fast enough to allow repeated spectrum evaluations for increasing burn-up values and, for this reason, it is well suited for reactivity-time calculations

Table 4 gives the percentage variations of ηf for a five-ring subdivision of a typical ORGEL-lattice cell (ECO fuel element) with reference to a 20-region THERMOS calculation.

Table 4

Comparison between 5-region and 20-region THERMOS evaluations of ECO fuel element

Fuel composition	$\Delta(\eta f)$ %
Natural U	-.03
Nat. U+0.05 % Pu	-.03
0.3% Pu+0.25% U-235	-.015

The upper energy limit of the thermal spectrum calculation is 2.2 eV. This means that the absorption in the 1-eV resonance of Pu-240 (as well as the 0.3 eV resonance of Pu-239) is taken into account here. The choice of including the Pu-240 resonance absorption in the thermal calculation has been made on the basis

of an analysis carried out at Ispra [17]. In this study, a large number of Pu-240 resonance integrals for heterogeneous systems have been calculated both by the use of standard codes (ZUT and ARES-II), where such effects as spatial flux non-uniformity in fuel and moderator, energy depression in the moderator and thermal motion of moderating nuclei are not taken into account, and more sophisticated methods (THERMOS and WDSN), where no approximation of this nature is introduced.As an illustration, the results obtained with the different calculation methods for a heavy water system are plotted in fig. 1 as a function of the fuel mean chord length. It can be seen that, in order to ensure that the error on the Pu-240 resonance integral never exceeds a few percent, it is necessary to include this calculation directly in the thermal part. The energy group-structure has been chosen in such a way as to provide a sufficient number of groups inside this 1-eV resonance.

Energy exchange between the fine thermal groups in heavy water, light water and graphite is accounted for through the Nelkin-Honeck, the Nelkin and the Parks kernels respectively. A kernel developed at Ispra [18] describes the interactions with the hydrogen atoms bound in the organic molecule. Collisions with other moderating nuclides are treated through the use of the free gas kernel.

1.3.2 Spatial flux distribution

The spatial variation of the thermal flux is determined by a one-group multiregion calculation. For light-water moderated lattices, collision probabilities are used everywhere.

In the cases of heavy water or graphite moderated systems, collision probabilities are used in the fuel channel and a layer of moderator (about one mean free path in thickness) immediately adjacent to the fuel element while the behaviour of the flux in the rest of the moderator is treated with diffusion theory. Total reaction cross sections are used wherever the collision probability technique is applied and transport cross sections elsewhere. The collision probabilities are obtained with the Bonalumi-Jonsson approximate method of calculation[10][19].

a) When diffusion theory is used in the moderator, the neutron current entering the fuel element is assumed to be isotropically distributed. The flux normalization at the fuel-moderator interface is effected by defining the extrapolation length in the fuel channel according to the well known method of Kushneriuk and McKay[20]. The neutron balance equations then read, for any region inside the channel, as

$$\Sigma_j \phi_j V_j = \sum_{i=1}^{N} \left[\Sigma_{A,i} \phi_i + q_i \right] V_i \left[P_{ij} + \frac{P_{io}}{P_o} P_{oj} \right] + q_M V_M \frac{P_{oj}}{P_o}$$

where P_{io} is the probability of escape from the channel for neutron born in ring i; P_{oi}, the probability that a neutron presenting itself at the fuel-moderator interface with an isotropic angular distribution will make its first collision in region i; Po is given by

$$P_o = \sum_{i=1}^{N} P_{oi}$$

N being the total number of annuli in the system. Index M refers to the moderator. The sources are obtained directly from the epithermal calculation.

b) When collision probabilities are used also in the moderator, the neutron balance equations assume a form completely analogous to the relationship used in the epithermal range, i.e. they constitute a particular case of the following formulation, valid for r thermal groups

$$\Sigma_{j,m}\phi_{j,m}V_j = \sum_{m=p+q+1}^{p+q+r}\sum_i \left[\Sigma_{i,m}q_{i,m\to m}\phi_{i,m} + q_{i,m}\right]V_i P_{ij,m} \qquad (p+q<m\leq p+q+r)$$

where

$$q_{j,m} = \sum_{m=1}^{p+q}\left[\Sigma_{j,m}q_{j,m\to m}\phi_{j,m}\right]$$

Since all fuel elements are represented as a network of concentric cylindrical annuli, the problem of cluster homogenisation must be faced. In order to evaluate the hyperfine structure of the flux in such geometries, an iterative procedure is resorted to. A subcell is defined as made up of a fuel pin, its cladding and a concentric annulus of coolant, the thickness of which is calculated by finding the amount of coolant that would be associated with every pencil if the cluster configurations were extended to infinity. The assumption is then made that the hyperfine structure of the flux in the central subcell pertains equally well to the other subcells. Thus, a first spatial problem is run to evaluate the hyperfine structure and the results are used to homogenize the materials in any subcell; a second spatial problem follows, which is based on those homogenised cross-

sections. It has been shown that further iterations will not yield significantly different results.

Once the average fluxes in the moderator and the channel annuli are known, it is a simple matter to evaluate the thermal multiplication factor through the standard relationship

$$\eta f = \frac{\sum_i [(\nu\Sigma_f)_i \, \phi_i \, V_i]}{\sum_i [(\Sigma_a)_i \, \phi_i \, V_i]} .$$

1.4 Neutron Leakage

Originally developed in the framework of the heavy water reactor programme, the code PINOCCHIO, in its present state, incorporates a calculation scheme for the treatment of neutron leakage which is well adapted to this type of lattices but is hampered by certain limitations in more general cases. The main features of the method are:

1) detailed treatment of cell heterogeneity, the clusters being represented as networks of concentric annuli;
2) use of transport-corrected cross sections to account for scattering anisotropy;
3) neglect of diffusion asymmetry;
4) group diffusion theory used in all cases. Thus in every group, the cell-homogenized absorption cross-section is incremented by a term $D_n B^2$ where the cell-averaged diffusion coefficient in group n is given by Benoist's formula

$$\frac{D_m}{D_{M,m}} = 1 + \frac{\phi_{M,m}}{\phi_{t,m}} \left\{ \sum_i \frac{V_i}{V_t} \left(1 - \frac{\lambda_{M,m}}{\lambda_{i,m}}\right) + \sum_i \sum_{j \neq i} \varepsilon_{ij} \frac{V_i}{V_t} \frac{\lambda_{j,m}}{\lambda_{M,m}} \left[\left(\frac{\phi_{i,m}}{\phi_{M,m}} - \frac{\lambda_{M,m}}{\lambda_{i,m}} \right) \left(1 - \frac{\lambda_{M,m}}{\lambda_{j,m}}\right) + \left(\frac{\phi_{j,m}}{\phi_{M,m}} - \frac{\lambda_{M,m}}{\lambda_{j,m}} \right) \left(1 - \frac{\lambda_{M,m}}{\lambda_{i,m}}\right) \right] P_{ij,m} \right\}$$

where

$$\varepsilon_{ij} = 1 \qquad (i \neq j)$$
$$= \tfrac{1}{2} \qquad (i = j)$$

The sums extend over every medium in the lattice except the moderator, referred to by the index M. The symbol ϕ_t denotes the cell-averaged flux, the λ's the transport mean free paths obtained directly from the GAM and GATHER homogeneous problems. The buckling is assumed to remain constant as a function of energy.

2. The Reactivity-Time Problem

Provision has been made in PINOCCHIO to perform a complete reactivity-time calculation for a given unit cell under the assumption that the power per unit length of channel does not vary. This, at least in principle, is no limitation since the history of any fuel element can always be represented by a series of PINOCCHIO calculations at different power levels.

At the present stage, the eigenvalue problem is solved anew and completely at each time step although in later versions it will be possible to keep the fast and epithermal parameters constant in successive time steps.

In the description of the isotopic evolution, the simplified chain structure proposed by England [21] constitutes, in PINOCCHIO, the reference model of fission product poisoning. For U-235, U-238 and Pu-239 progeny, England has identified 14 chains containing 54 nuclides which produce approximately 95 percent of the total poison, the remaining 5 percent being adequately represented by the introduction of 2 pseudo-nuclides. However, for routine calculations and provided the maximum irradiation does not exceed 15,000 MWD/T,

this representation is still unnecessarily complex. Accordingly an alternate picture consisting of 18 fission products in 6 linear chains, plus 2 pseudo-nuclides, is also included in the code: it has been verified that this structure is sufficiently detailed for the total poison to be reproduced within 5% at the maximum irradiation considered[22]. In both descriptions of fission product poisoning, direct contributions due to Xe-135 and SM-149 have been excluded.

The code does take into account the fact that the isotopic evolution is not the same in each pin ring of a fuel cluster due to the non-uniformity of the spatial flux distribution.

Acknowledgments

Many people have contributed to the development of the code PINOCCHIO. The guidance and support of Dr. V. Raievski and Prof. A. Kind is gratefully acknowledge. Mr. F. Beonio-Brocchieri was responsible for the work connected with the analysis of the fuel isotopic evolution while Mr. W. De Haan has obtained the correlation equations for the resonance integrals of the fertile and fissile isotopes. Mr. E. Diana has studied various apsects of the thermal spectrum and formulated the output parameters to be used in heterogeneous codes. Thanks are also due to Messrs. S. Stramaccia and R. Meelhuysen for their contributions to the programming. The helpful criticism of Messrs. B. Sturm and M. Paillon have led to a number of improvements in the successive versions of the code.

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Part II

CODE DESCRIPTION

1. Generalities

1.1 Materials

The composition of the materials which constitutes the cell is expressed in the PINOCCHIO input in terms of atomic densities. (nuclei/barn.cm). A maximum of ten compositions can be considered which correspond to the following ten regions of the cell:

1) Fuel 1
2) Fuel 2
3) Fuel 3
4) Canning
5) Coolant
6) Filler
7) Pressure tube
8) Insulating layer
9) Calandria tube
10) Moderator

The geometries specifically provided for in the current version are described in Table 1 and illustrated in Figs. 2-5. The three fuel compositions correspond to different fuel regions in the cluster depending on the geometry configuration:

single rod : the rod is divided in 3 fuel rings of equal thickness
fuel 1 = central ring, fuel 2 = intermediate ring,
fuel 3 = outer ring

4 rod cluster : only one fuel region is considered (fuel 2 and fuel 3 absent);

7 rod cluster : fuel 1 = central pin, fuel 2 = 1st fuel pin ring, fuel 3 = absent;

19 rod cluster : fuel 1 = central pin, fuel 2 = 1st fuel pin ring, fuel 3 = 2nd fuel pin ring;

37 rod cluster : fuel 1 = 7 central pins, fuel 2 = 2nd fuel pin ring, fuel 3 = 3rd fuel pin ring.

1.2 Isotopes and Library

A list of isotopes that are included in the present version of the code library is given in Table 5. Each isotope is identified by two identification numbers (ex. 14002 40). The five numbers which compose the first identification number are chosen in the following way:

1st number (= 0 or blank) = microscopic thermal cross-sections do not depend on temperature (non-moderator isotopes),
(= 1) = the isotopes is present in the library at several temperatures (moderator);
2nd number (= 0 or 1 or 2etc.) identifies the model used in the scattering kernel at thermal energies;
3rd to 5th number = identify the isotope.

The second identification number is equal to the isotope temperature in (°C). This second identification is not given in input for each isotope, but it is assigned to each material, as it is clear that all isotopes which belong to the same material are at the same temperature. According to this, the choice of the temperature must be made by paying attention that the temperature value will be used as the second identification number of the moderator isotopes (i.e. of isotopes with a first identification number with 1 as first number) and the pair of identifications must be as listed in Table 5.

When more than one fuel region is considered the temperature used for Doppler broadening calculation of resonance integrals is the FUEL 1 temperature and not the average value for the fuel. Apart from the composition of each material, a list of the identification number of resonance isotopes present in the fuel must be given by the user. For these isotopes microscopic scattering and capture epithermal cross-sections are obtained through resonance integrals. These isotopes are identified by a single identification number, and have to be chosen among those in section III of Table 5.

The diagnostic"Program ERROR Stop 101" printed in output means that the list of isotopes identifications given in input is incorrect.

The PINOCCHIO library is divided into 5 sections:

1) Thermal cross sections
2) Fast and epithermal cross sections
3) Resonance integral coefficients
4) Fissile isotopes and fission products for burn-up calculations
5) Chain composition for burn-up calculations

The total number of isotopes considered must be ≤ 50; in the evaluation of the total number of isotopes, both the first and second identification numbers have to be considered, that is to say for example that (12001 27) and (12001 70) will be considered by the code as two isotopes.

1.3 Few-group parameters

Few-group macroscopic cross sections for use in diffusion calculation and heterogeneous parameters for use in the SOS code are calculated by PINOCCHIO. The parameters are averaged values for channel (fuel element and tubes) moderator and cell. Broad group limits for few-group parameters calculations must be given in the input, but each broad group must always includes an integral number of PINOCCHIO groups. The 1st and 2nd PINOCCHIO fine groups must always belong to the same broad group. The last broad group must be the thermal group of PINOCCHIO (group 10).

The heterogeneous parameters are calculated only for the 4 broad group option. From high to low energy, for each group the lower energy limit must be specified in the input data, by giving the ordinal number NDG (I) (see input data card 3) corresponding to the lower PINOCCHIO fine group in the broad group.

2. Code Language

PINOCCHIO , written in FORTRAN IV, can be run on a normal IBM 360/65 following the O.S. monitor, in the HAPS system. The total number of bytes occupied is 153.854 including all library subroutines and special functions. The compilers used are FORTRAN G (LEVEL ONE) and FORTRAN H (LEVEL ZERO).

Table 5

Isotopes in PINOCCHIO library

Thermal cross sections

ELEM.	1st IDENT.	2nd IDENT.	MODEL
H	10001	27	FREE GAS
	10001	40	" "
	10001	50	" "
	10001	60	" "
	10001	70	" "
	10001	80	" "
	10001	90	" "
	12001	27	H in H_2O without transp. correct.
	14001	27	H in H_2O with transp. correct.
	12001	70	H in H_2O
	12001	150	" " "
	12001	250	" " "
	12001	350	" " "
	13001	27	ARDENTE MODEL
	13001	100	" "
	13001	150	" "
	13001	200	" "
	13001	250	" "
	13001	300	" "
	13001	350	" "
	13001	400	" "
	13001	450	" "
D	10002	27	FREE GAS
	10002	50	" "
	10002	90	" "
	10002	100	" "
	10002	150	" "
	10002	200	" "
	10002	250	" "
	10002	300	" "
	12002	27	NELKIN MODEL
	12002	40	from GAKER 101 groups)
	12002	50	" "
	12002	60	" "
	12002	70	" "
	12002	80	" "
	12002	90	" "

Thermal cross sections

ELEM.	1st IDENT.	2nd IDENT.	MODEL
D	14002	27	NELKIN MODEL
	14002	40	(from GAKER 30 groups)
	14002	50	" "
	14002	60	" "
	14002	70	" "
	14002	80	" "
	14002	90	" "
C	10012	27	FREE GAS
	10012	100	" "
	10012	150	" "
	10012	177	" "
	10012	200	" "
	10012	250	" "
	10012	300	" "
	10012	350	" "
	10012	400	" "
	10012	450	" "
	10012	620	" "
	10012	627	" "
	10012	700	" "
	10012	720	" "
	10012	800	" "
	10012	820	" "
	10012	900	" "
	10012	927	" "
	10012	1000	" "
	10012	1100	" "
	10012	1200	" "
	10012	1300	" "
	10012	1400	" "
	10012	1500	" "
	15012	27	PARKS KERNEL
O	10016	27	FREE GAS
	10016	40	" "
	10016	50	" "
	10016	60	" "
	10016	70	" "
	10016	80	" "
	10016	90	" "
	10016	150	" "
	10016	177	" "
	10016	250	" "
	10016	350	" "

Thermal cross sections

ELEM.	1st IDENT.	2nd IDENT.	MODEL
O	10016	627	FREE GAS
	10016	700	" "
	10016	800	" "
	10016	900	" "
	10016	1000	" "
	10016	1100	" "
	10016	1200	" "
	10016	1300	" "
	10016	1400	" "
	10016	1500	" "
Fe	26	27	
Al	27	27	
Zr	40	27	
Th232	232	27	
U235	235	27	
U236	236	27	
U238	238	27	
Pu239	239	27	
Pu240	240	27	
Pu240	10240	177	Dopp. Broadened
	10240	327	" "
	10240	627	" "
	10240	927	" "
Pu241	241	27	
Xe	135	27	
Bo	10	27	
Mg	24	27	
Cr	52	27	
Mn	55	27	
Ni	58	27	
Cu	63	27	
Nb	93	27	
Cd	112	27	
Sn	119	27	
Pb	207	27	
Sm	149	27	
U233	133	27	
Pa233	533	27	
Np239	539	27	

Fast and epithermal cross sections

ELEM.	1st IDENT.	2nd IDENT.
H	1	27
D	2	27
Bo	10	27
C	12	27
O	16	27
Mg	24	27
Fe	26	27
Al	27	27
Zr	40	27
Cr	52	27
Mn	55	27
Ni	58	27
Cu	63	27
Nb	93	27
Cd	112	27
Sn	119	27
Xe	135	27
Sm	149	27
Pb	207	27
Th	232	27
U233	233	27
U235	235	27
U236	236	27
U238	238	27
Pu239	239	27
Pu240	240	27
Pu241	241	27
Pa233	533	27
Np239	539	27

Resonance integral coefficients

h	232	27
235	235	27
238	238	27

Fissile isotopes and fission products for BURN-UP

U233	233	1
U235	235	2
U238	238	3
Pu239	239	4
Pu241	241	5

Fissile isotopes and fission products for BURN-UP

ELEM.	1st IDENT.	2nd IDENT.
Pu242	242	6
Th232	232	7
Th233	433	8
Pa233	533	9
U234	234	10
U236	236	11
U239	439	12
Np239	539	13
Pu240	240	14
Rh105	105	15
Pd105	305	16
Nd145	145	17
Nd146	146	18
Nd147	147	19
Pm147	347	20
Pm148m	148	21
Pm148	348	22
Pm149	349	23
Sm149	149	24
Sm150	150	25
Sm151	351	26
Sm152	152	27
Sm153	353	28
Eu153	153	29
Eu154	154	30
I135	335	31
Nd150	350	32
Pm151	451	33
Pm148m	448	34
Pm148	542	35
Xe135	135	36
*PF(1)	301	37
*PF(2)	302	38
*PF(3)	303	39
*PF(4)	304	40
Zr95	95	41
Nb95	295	42
Mo95	395	43
Te99	99	44
Ru100	100	45
Ru101	101	46
Ru102	102	47

Fissile isotopes and fission products for BURN-UP

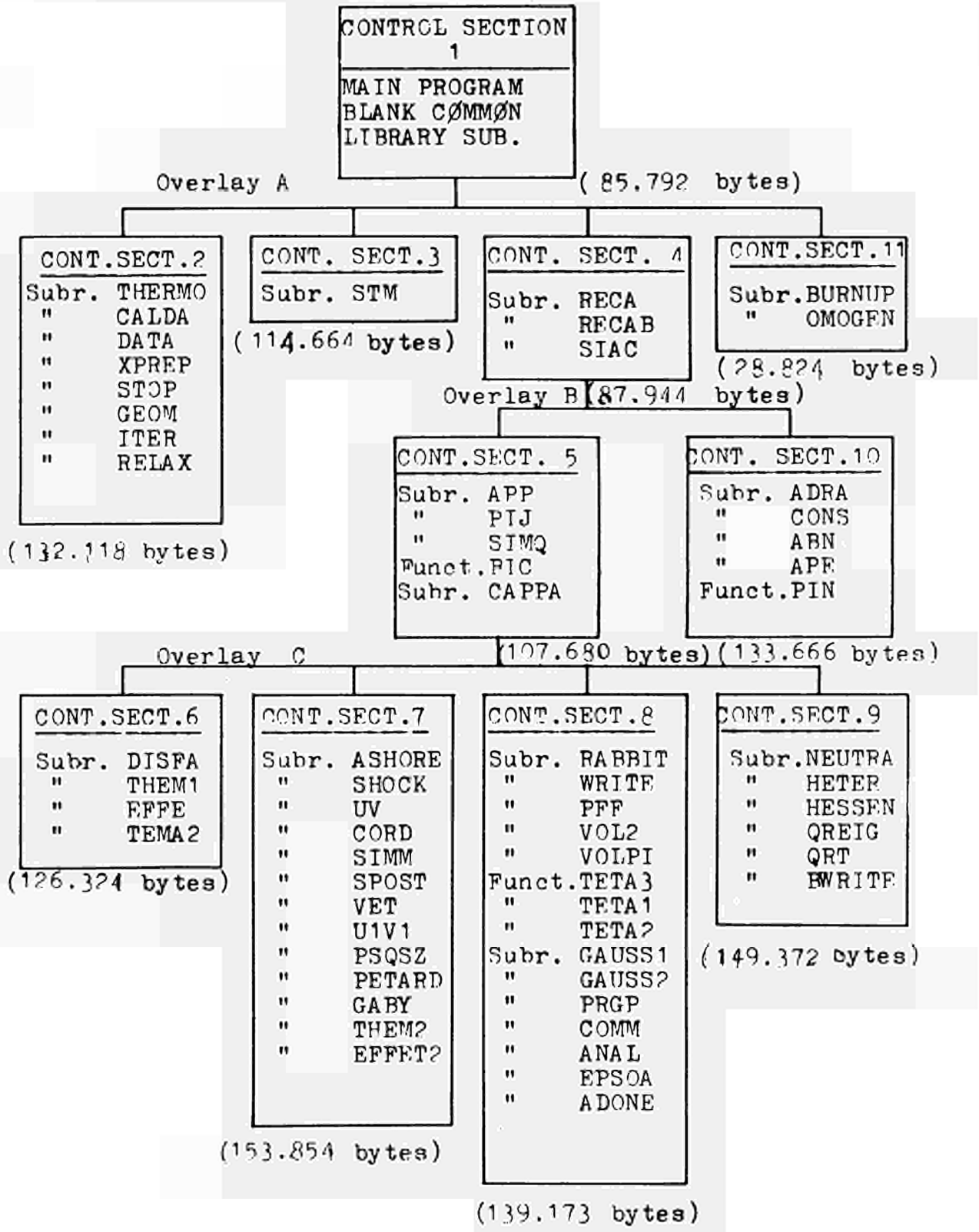
ELEM.	1st IDENT	2nd IDENT.
Ru103	103	48
Rh103	403	49
Pd104	104	50
Nd148	648	51
Pd106	106	52
Eu155	155	53
Pd107	107	54
Pd108	108	55
Ag109	109	56
Te131m	131	57
I131	331	58
Xe131	431	59
I133	133	60
Xe133	333	61
Xe134	134	62
Mo99	299	63
Cs133	633	64
Cs134	334	65
Ce143	143	66
Pr143	343	67
Nd143	443	68
*PF(5)	306	69
Eu157	157	70
Gd157	357	71
*PF(6)	307	72
*PF(7)	308	73

Chain composition from chain 1 to chain 25

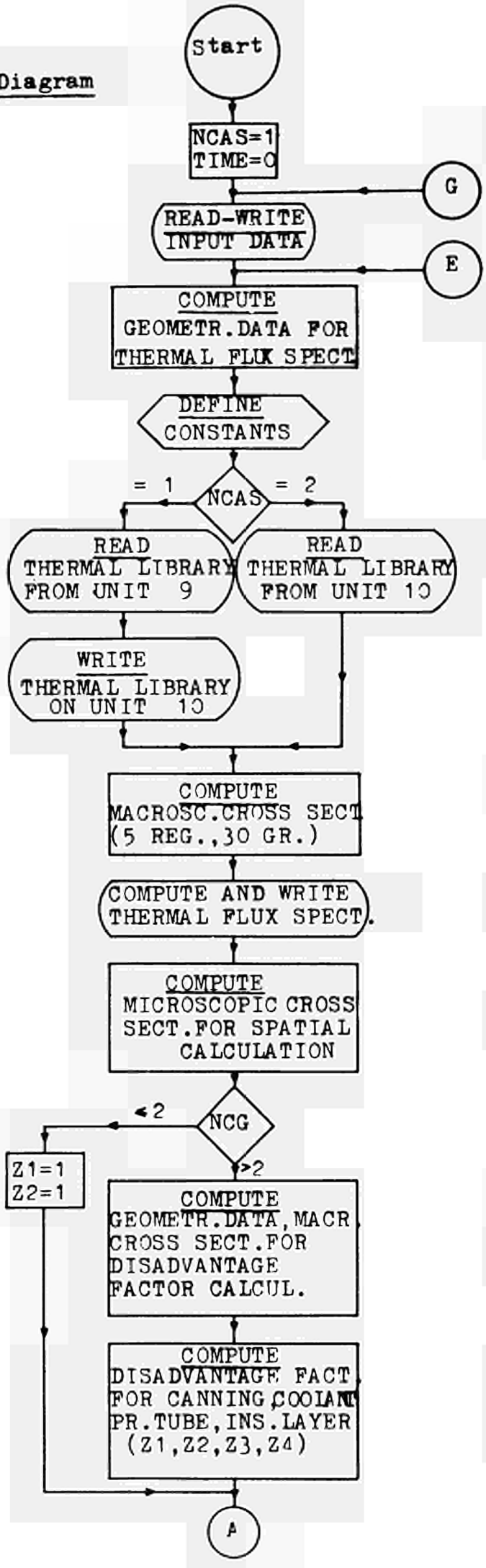
- . - . -

* PF(I) : Pseudo-fission products.

3. Overlay organisation



4. Flow-Diagram



Main PINO

Subr. THERMO,CALDA

Subr. THERMO

Subr. DATA

Subr. XPREP, STOP

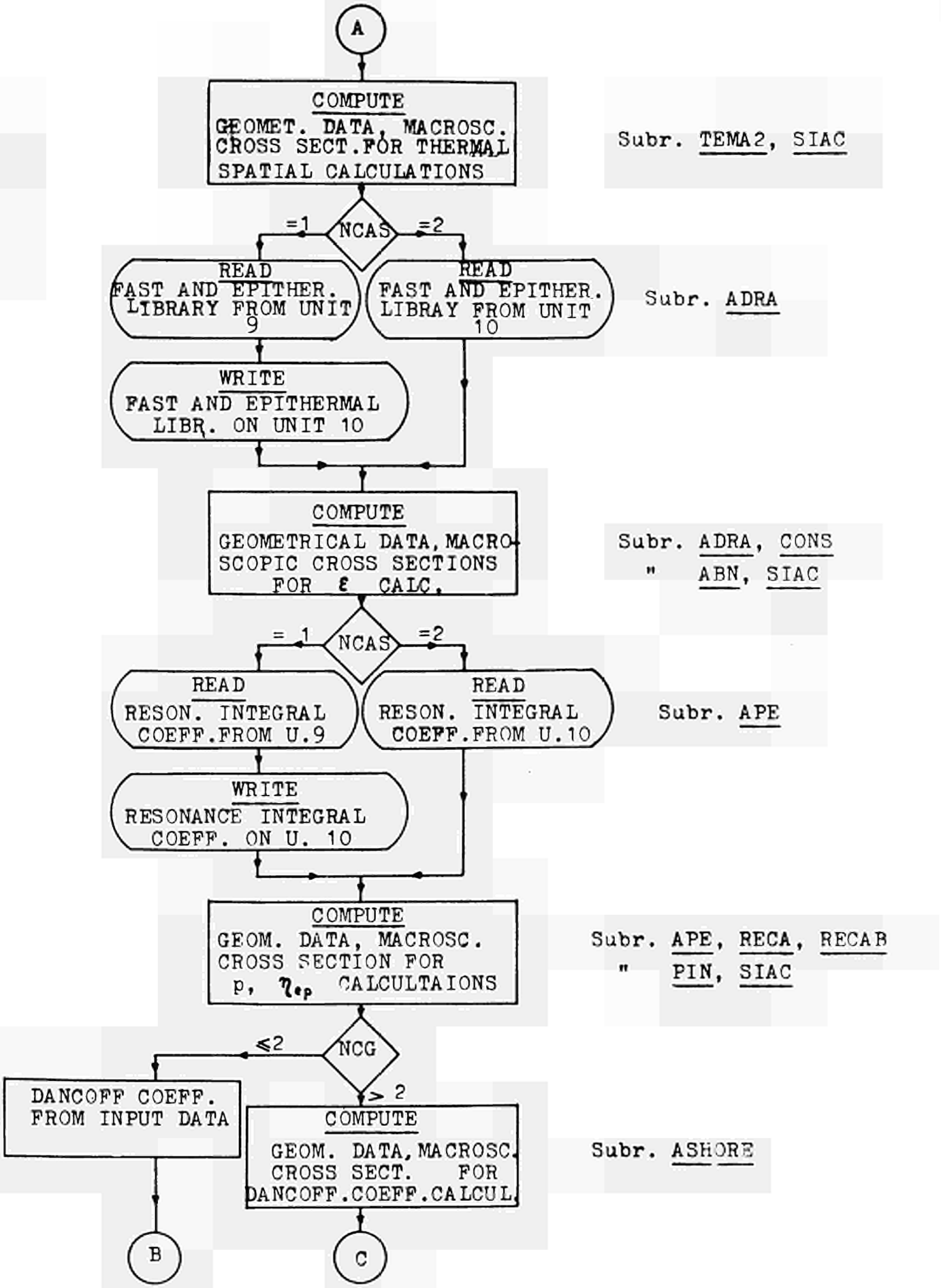
Subr. XPREP, GEOM.

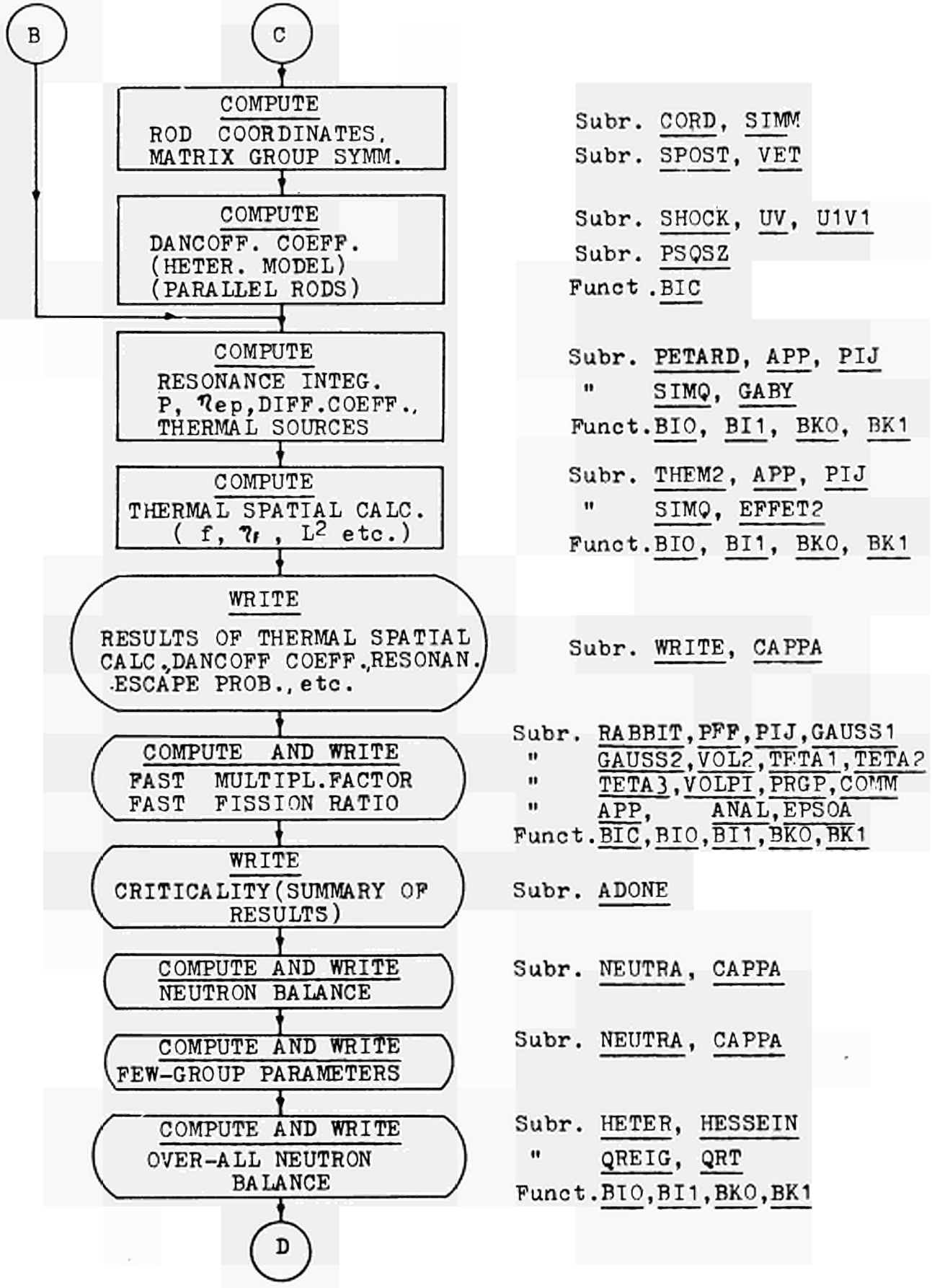
Subr. ITER, RELAX

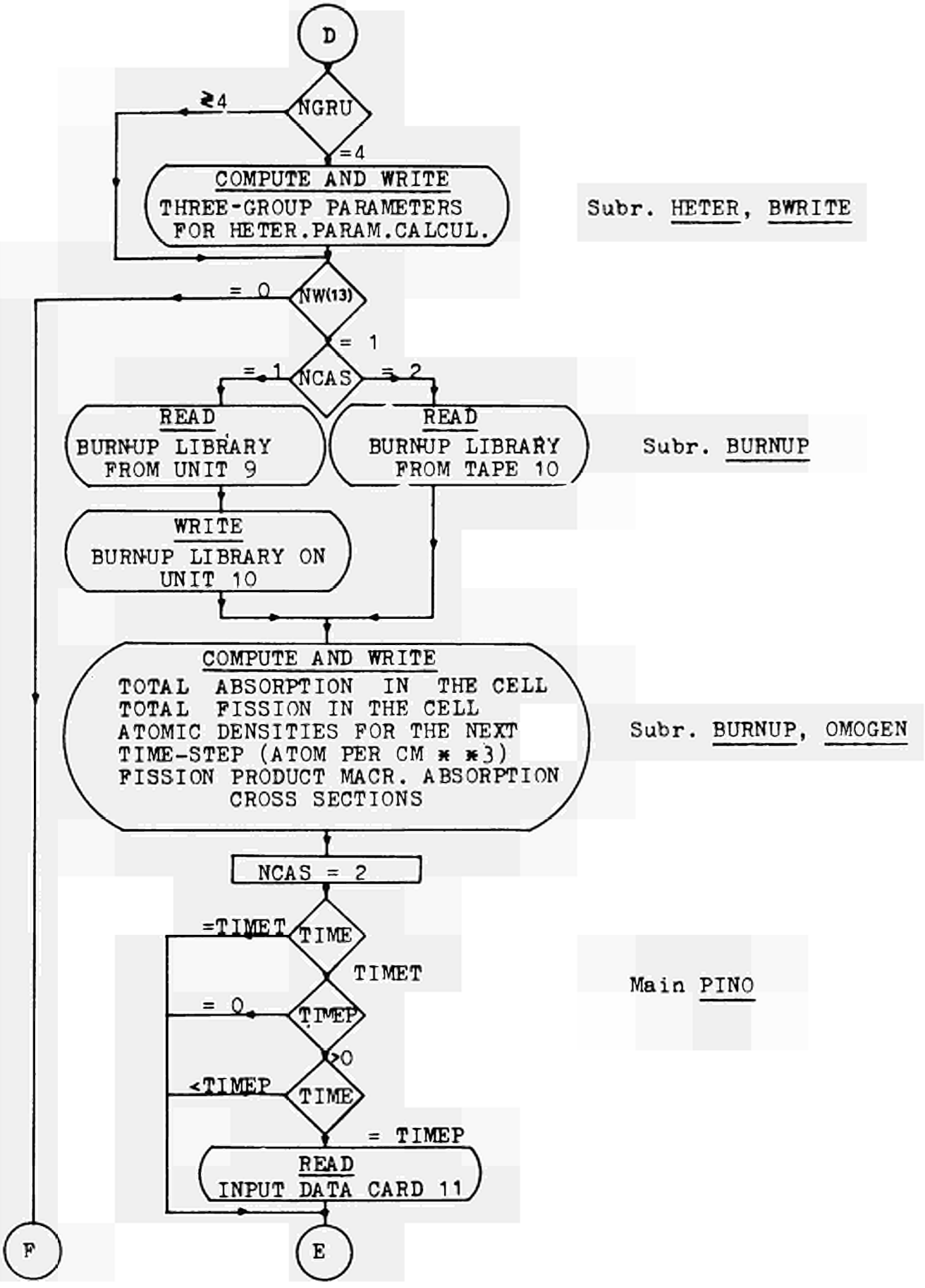
Subr. STM

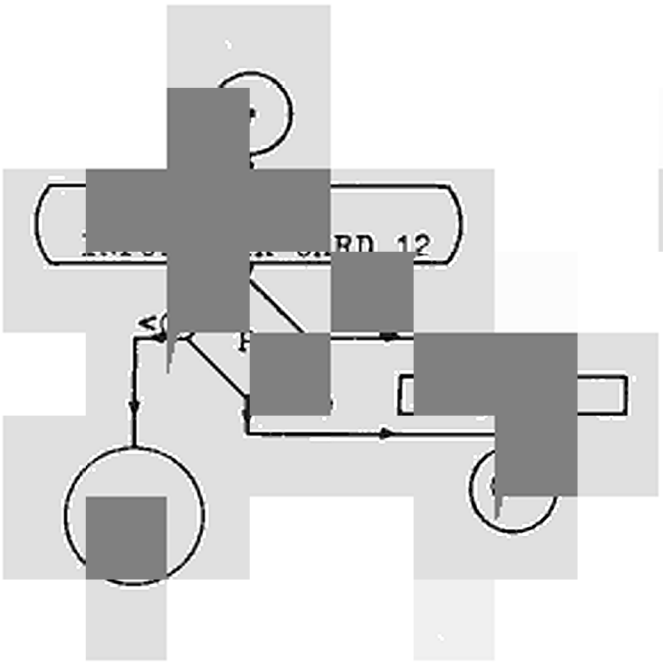
Subr. DISFA, RECA
Subr. RECAB

Subr. THEM1, EFFE
Subr. APP, PIJ, SIMQ
Funct. BIO, BKO, BI1
BK1


A
COMPUTE
GEOMET. DATA, MACROSC. CROSS SECT. FOR THERMAL SPATIAL CALCULATIONS
Subr. TEMA2, SIAC
NCAS
=1
=2
READ
FAST AND EPITHER. LIBRARY FROM UNIT 9
READ
FAST AND EPITHER. LIBRAY FROM UNIT 10
Subr. ADRA
WRITE
FAST AND EPITHERMAL LIBR. ON UNIT 10
COMPUTE
GEOMETRICAL DATA, MACROSCOPIC CROSS SECTIONS FOR ε CALC.
Subr. ADRA, CONS
" ABN, SIAC
NCAS
= 1
=2
READ
RESON. INTEGRAL COEFF. FROM U.9
READ
RESON. INTEGRAL COEFF. FROM U.10
Subr. APE
WRITE
RESONANCE INTEGRAL COEFF. ON U. 10
COMPUTE
GEOM. DATA, MACROSC. CROSS SECTION FOR p, η_{ep} CALCULTAIONS
Subr. APE, RECA, RECAB
" PIN, SIAC
NCG
≤2
> 2
DANCOFF COEFF. FROM INPUT DATA
COMPUTE
GEOM. DATA, MACROSC. CROSS SECT. FOR DANCOFF.COEFF.CALCUL.
Subr. ASHORE
B
C


B
C
COMPUTE
ROD COORDINATES,
MATRIX GROUP SYMM.
Subr. CORD, SIMM
Subr. SPOST, VET
COMPUTE
DANCOFF. COEFF.
(HETER. MODEL)
(PARALLEL RODS)
Subr. SHOCK, UV, U1V1
Subr. PSQSZ
Funct. BIC
COMPUTE
RESONANCE INTEG.
P, ηep, DIFF.COEFF.,
THERMAL SOURCES
Subr. PETARD, APP, PIJ
" SIMQ, GABY
Funct. BIO, BI1, BKO, BK1
COMPUTE
THERMAL SPATIAL CALC.
(f, ηf , L2 etc.)
Subr. THEM2, APP, PIJ
" SIMQ, EFFET2
Funct. BIO, BI1, BKO, BK1
WRITE
RESULTS OF THERMAL SPATIAL
CALC.,DANCOFF COEFF.,RESONAN.
ESCAPE PROB., etc.
Subr. WRITE, CAPPA
COMPUTE AND WRITE
FAST MULTIPL.FACTOR
FAST FISSION RATIO
Subr. RABBIT, PFF, PIJ, GAUSS1
" GAUSS2, VOL2, TETA1, TETA2
" TETA3, VOLPI, PRGP, COMM
" APP, ANAL, EPSOA
Funct. BIC, BIO, BI1, BKO, BK1
WRITE
CRITICALITY (SUMMARY OF
RESULTS)
Subr. ADONE
COMPUTE AND WRITE
NEUTRON BALANCE
Subr. NEUTRA, CAPPA
COMPUTE AND WRITE
FEW-GROUP PARAMETERS
Subr. NEUTRA, CAPPA
COMPUTE AND WRITE
OVER-ALL NEUTRON
BALANCE
Subr. HETER, HESSEIN
" QREIG, QRT
Funct. BIO, BI1, BKO, BK1
D


D
NGRU
≥4
=4
COMPUTE AND WRITE
THREE-GROUP PARAMETERS
FOR HETER.PARAM.CALCUL.
Subr. HETER, BWRITE
= 0
NW(13)
= 1
= 1
NCAS
= 2
READ
BURNUP LIBRARY
FROM UNIT 9
READ
BURNUP LIBRARY
FROM TAPE 10
Subr. BURNUP
WRITE
BURNUP LIBRARY ON
UNIT 10
COMPUTE AND WRITE
TOTAL ABSORPTION IN THE CELL
TOTAL FISSION IN THE CELL
ATOMIC DENSITIES FOR THE NEXT
TIME-STEP (ATOM PER CM * *3)
FISSION PRODUCT MACR. ABSORPTION
CROSS SECTIONS
Subr. BURNUP, OMOGEN
NCAS = 2
=TIMET
TIME
TIMET
= 0
TIMEP
>0
<TIMEP
TIME
= TIMEP
READ
INPUT DATA CARD 11
Main PINO
F
E


Main
RD 12

5. Execution Time

The execution time of a typical cell calculation varies from 1 minute in the case of single rods (geometry N° 1 : Table 1) to 3 minutes for geometry N° 13. This time is reduced by 10-20% in the case in which the same calculation is repeated for different pitches. In fact in this case the library tape must be read completely only once to locate the isotopes of interest.

For burn-up problems, the machine-time is somewhat reduced since the data must only be read for the first time-step. Thus, a single 19-rod problem requires of the order of 2 minutes, but 12 time-steps may be run in 15 minutes for the same lattice cell.

6. Input Data Specification

Word	1					
Column	1-72					
Format	18A4					
Card 1	Problem identification and description					
Symbol	TITLE					

Word	1	2	3	4	5	6
Column	1-2	4	5-6	8	10	11-12
Format	I2	I1	I2	I1	I1	I2
Card 2	Geometry index (see Table 1)	=1 square lattice =2 triangular lattice	Number of isotopes present in the cell *	Number of broad groups for few-group parameters calculation (≤ 9) **	=1 Simplified burn up calc. =2 Detailed burn-up calc. (see burnup) ***	Number of time-steps for complete cell calc. and for the given PU (see card8 word 4) (≤ 99)
Symbol	NCG	NTR	NE	NGRU	NBU	NSTEP

* The isotope present at several temperatures must be considered only once. See "isotopes and library"
** NGRU=4 if heterogeneous parameters are wanted
*** If burn-up is not wanted column 10-49 must be blank

Word	7	8	9	10	11	12-35
Column	14	16	17-18	20	25	26-49
Format	I1	I1	I2	I1	I1	24I1
Card 2 (continued)	Number of time-steps for thermal calculation only (spectral and spatial) (always equal to 1)	Number of time-steps for thermal calculation only (spatial) (always equal to 1)	Number of time-steps for depletion chains calculation (≤ 99)	=0 Atomic densities are read (see card 9-10) =1 Atomic densities are calculated (not yet possible	=0 Chain 1 is not considered in burn-up calcul. =1 Chain 1 is considered	As the column 25 for the chains from 2 to 25
Symbol	N1	N2	N3	NCC	NUCAT(1)	NUCAT(2-25)

Word	36	37	38	39	40	41
Column	55	56	57	58	59	60
Format	I1	I1	I1	I1	I1	I1
Card 2 (continued)	=0 General description (input data) will not be printed out =1 will be printed	=0 Thermal parameters (THERMOS, THEMIS results) will not be printed =1 will be printed	=0 Ephithermal parameters (PETARD, SHOCK results) will not be printed =1 will be printed	=0 Fast parameters (RABBIT results) will not be printed =1 will be printed	=0 Criticality (summary of results) will not be printed =1 will be printed	=0 Neutron balance will not be printed =1 will be printed
Symbol	NW(1)	NW(2)	NW(3)	NW(4)	NW(5)	NW(6)

Word	42	43	44	45	46	47
Column	61	62	63	64	65	66
Format	I1	I1	I1	I1	I1	I1
Card 2 (continued)	=0 Few-group parameters (cell averaged) will not be printed =1 will be printed	=0 Few-group parameters (moderator averaged) will not be printed =1 will be printed	=0 Few-group parameters (fuel-averaged) will not be printed =1 will be printed	=0 Over-all neutron balance will not printed =1 will be printed	=0 Three-group parameters for heterogeneous par. will not be printed =1 will be printed	=0 Three-group heterogeneous parameters will not be printed =1 will be printed
Symbol	NW(7)	NW(8)	NW(9)	NW(10)	NW(11)	NW(12)

Word	48	49				
Column	67	68				
Format	I1	I1				
Card 2 (continued)	=0 Burnup (cross sections for the time-step) will not be printed =1 will be printed *	=0 Atomic densities for the next time-steps will not be printed =1 will be printed				
Symbol	NW(13)	NW(14)				

* N(13)=0 the burn-up will not be calculated

Word	1	2	3	4	5	etc.
Column	5	9-10	14-15	19-20	24-25	etc.
Format	I1	I2	I2	I2	I2	etc.
Card 3	1st Broad-group limit =9 if NGRU=2 =2 if NGRU>2	2nd Broad-group limit =10 if NGRU=2 = 9 if NGRU=3	3rd Broad-group limit	etc.		
Symbol	NDG(1)	NDG(2)	NDG(3)	until NDG(NGRU)		

See "few-groups parameters"

Word	1	2	3	4	5	6
Column	1-5	6-10	11-15	16-20	21-25	26-30
Format	I5	I5	I5	I5	I5	I5
Card 4	Temp.(°C) for fuel 1 material	Temp.(°C) for fuel 2	Temp.(°C) for Fuel 3	Temp.(°C) canning	Temp.(°C) coolant	Temp.(°C) filler
Symbol	IEM(1)	IEM(2)	IEM(3)	IEM(4)	IEM(5)	IEM(6)

Word	7	8	9	10		
Column	31-35	36-40	41-45	46-50		
Format	I5	I5	I5	I5		
Card 4	Temp.(°C) Pressure tube	Temp.(°C) Insulating layer	Temp.(°C) calandria tube	Temp.(°C) Moderator		
Symbol	IEM(7)	IEM(8)	IEM(9)	IEM(10)		

Word	1	2	3	4	5	
Column	3-5	8-10	13-15	18-20	23-25	
Format	I3	I3	I3	I3	I3	
Card 5	1st resonance isotope Identification number	2nd resonance isotope Identification number	3rd resonance isotope Identification number	4th resonance isotope Identification number	5th resonance isotope Identification number	
Symbol	ISRIS(1)	ISRIS(2)	ISRIS(3)	ISRIS(4)	ISRIS(5)	

See "Isotopes and library"

Number of resonance isotopes≤5

Word	1	2	3	4	5	
Column	1-8	10-17	19-26	28-35	37-44	
Format	E8.4	E8.4	E8.4	E8.4	E8.4	
Card 6	Radius of fuel pins (cm)	External radius of canning (cm)	First ring of rod center circle radius(cm) 0 if NCG=1,2	Pitch(cm)	Dancoff coeff.for NCG=1.2	
Symbol	RF	RC	R1	P	CDBU	

Word	1	2	3	4	5	6
Column	1-8	10-17	19-26	28-35	37-44	46-53
Format	E8.4	E8.4	E8.4	E8.4	E8.4	E8.4
Card 7	Internal radius of pressure tube (cm)	External radius of pressure tube (cm)	Internal radius of calandria tube (cm)	External radius of calandria tube (cm)	Volume filler external to the rubber band (cm^2)	Volume filler internal to the rubber band (cm^2)
Symbol	RTI	RTE	RCI	RCE	FIL1	FIL2

This card is to be supplied only if NCG=2,4,5,7, 10,11,13

Word	7					
Column	55-62					
Format	E8.4					
Card 7 (continued)	Volume filler in the center of the rod (cm^2). Only for the 4-rod cluster					
Symbol	FIL3					

Word	1	2	3	4	5	6
Column	1-8	10-17	19-26	28-35	37-44	46-53
Format	E8.4	E8.4	E8.4	E8.4	E8.4	E8.4
Card 8	Fuel density (gr/cm^3)	Experimental buckling used in the Keff calculation (leakage terms)	Convergence criterion, if 0 standard option $EPS=1.10^{-}$ is used *	Fission rate in the cell **	Time-step length for every NSTEP (see card 2 word 6)	Conversion factor for the decade constants in $sec.^{-1}$
Symbol	RHO	B2EX	EPS	PU	DELTAT	ALFA

* Neutron density convergence criterion in THERMOS flux calculation
** See "burn-up"

Word	7	8				
Column	55-62	64-71				
Format	E8.4	E8.4				
Card 8 (continued)	Time at end of burn-up calcula-tion	Time at wich the PU value will be changed				
Symbol	TIMET	TIMEP				

Word	1	2	3	4	5	6
Column	1-5	10-17	19-26	28-35	37-44	46-53
Format	I5	E8.4	E8.4	E8.4	E8.4	E8.4
Card 9	First iden-tification number of the isoto-pe I (see "Iso-topes and Library")	Density (nuclei/ barn cm) of the iso-tope I in the mat. fuel 1	Density iso-tope I in the mat. fuel 2	Density isotope I in fuel 3	Density iso-topes I in canning	Density isotope I in coolant
Symbol	ISTBA(I)	EN(I,1)	EN(I,2)	EN(I,3)	EN(I,4)	EN(I,5)

Card 9 and card 10 need to be re-peated NE times (see card 2 word 3)

Word	7	8				
Column	55-62	64-71				
Format	E8.4	E8.4				
Card 9 (continued)	Density isotopes I in filler	Density isotopes I in pressure tube				
Symbol	EN(I,6)	EN(I,7)				

Word	1	2	3			
Column	1-8	10-17	19-26			
Format	E8.4	E8.4	E8.4			
Card 10	Density isotopes I in ins. layer	Density isotopes I in calandria tube	Density isotopes I in moderator			
Symbol	EN(I,8)	EN(I,9)	EN(I,10)			

Word	1	2	3	4	5	6
Column	1-2	4	6	7-8	10-17	19-26
Format	I2	I1	I1	I2	E8.4	E8.4
Card 11	Number of time-steps for the new value of PU (≤ 99)	= 1 (see card 2word 7)	= 1 (see card 2 word 8)	Number of time-steps for depletion chains calculation (≤ 99)	Fission rate in the cell	Time-steps length for every NSTEP (see word 1)
Symbol	NSTEP	N1	N2	N3	PU	DELTAT

This card is to be supplied only if burn-up calcul. is wanted, if

0 < TIMEP < TIMET

(see card 8 word 7-8) and must be repeated until TIMEP = TIMET

Word	7					
Column	28-35					
Format	E8.4					
Card 11 (continued)	Time from zero to the moment at wich the PU value will be changed					
Symbol	TIMEP					

Word	1	2				
Column	1-8	10-17				
	E8.4	E8.4				
Card 12	New value of the pitch (cm) for a calculation of the cell given *	Experimental buckling for the new pitch				
Symbol	P	B2EX				

* If this is a blank card the next problem will be a completely new problem, thus repeat input starting with card 1

* P = -1 no more problems

7. Example of Input

```
   12345678901234567890123456789012345678901234567890123456789012345678901234567890
 1 ISPRA 6/2/68 UC/7/23.5 DIPHYL/D2Ø 99.73 NELKIN MØDEL EXPØ ECØ ZED-2 P   1-TITLE
 2  7 1 7 4                                              111111111111      2-ØPT.
 3     2    4    9   10                                                    3-GRØUP
 4    27   27   27   27   27   27   27   27   27   27                       4-TEMP.
 5   235  238                                                              5-RIS.
 6 1.2600+0 1.3750+0 2.9500+0 2.3500+1                                     6-GEØM 1
 7 4.5500+0 4.7500+0 5.0500+0 5.2000+0                                     7-GEØM 2
 8 1.3540+1 3.3700-4                                                       8-B2EX
 9 12001                                        3.8616-2                   9-CØNC.
10                   1.7932-4                                              10-CØNC.
11 10012    3.2620-2 3.2620-2                   4.6340-2                   9
12                                                                         10
13   235    2.3291-4 2.3291-4                                              9
14                                                                         10
15   238    3.2387-2 3.2387-2                                              9
16                                                                         10
17 10016                                        2.7624-3                   9
18                   3.3207-2                                              10
19    27                               5.2727-2                   6.0293-2 9
20          6.0293-2                                                       10
21 12002                                                                   9
22                   6.6234-2                                              10
23                                                                         12-BLANK
24 ISPRA 6/2/68 BURN-UP SINGLE ROD PITCH 15.6849                           1-TITLE
25  2 1 8 2 2 1 1 1 4 0     11         111111111111      1   1    1  11    2-ØPT.
```

1	9 1	0							3-GROUP
2	600 60	0 600	27 150	27 27	27 27	60			4-TEMP.
3	235 23	8							5-RIS.
4	1.7272+0	1.9280+0	0.0000+0	156849+0	0.0000+0				6-GEØM 1
5	2.0768+0	2.2098+0	2.2098+0	2.2098+0					7-GEØM 2
6	1.0422+1	0.0000+0	0.0000+0	41000+13	3.0000+6	1.0000+0	9.0000+6	3.0000+6	8-BURNUP
7	235	3.4351-4	3.4351-4	3.4351-4					9-CØNC.
8									10-CØNC.
9	238	473543-3	473543-3	473543-3					9
10									10
11	239	10000-12	10000-12	10000-12					9
12									10
13	240	10000-12	10000-12	10000-12					9
14									10
15	27				0.6020-1			0.6020-1	9
16									10
17	12001					0.6700-1			9
18									10
19	10016					0.3350-1			9
20			0.3310-1						10
21	12002								9
22			0.6620-1						10
23	1 1 1 8	20500+13	6.0000+6	9.0000+6					11-PU
24	-1.								12-END

8. Sample Output

```
                    * CCR EURATOM *
                * REACTOR PHYSICS DEPARTMENT *
                * REACTOR THEORY AND ANALYSIS *

*****************************************
*                                       *
*              * PINOCCHIO *            *
*       PIN OR CONCENTRIC CYLINDERS     *
*       HETEROGENEOUS INVESTIGATION     *
*                 OF ORGEL              *
*                                       *
*   L. AMYOT - G. CASINI - R. CUNIBERTI *
*          C. DAOLIO - A. KIND          *
*                                       *
*              DECEMBER 1967            *
*                                       *
*****************************************
```

```
ISPRA 6/2/68 UC/7/23.5 DIPHYL/D2O 99.73 NELKIN MODEL EXPO ECO ZED-2 P

1) GENERAL DESCRIPTION

GEOMETRY

     NUMBER OF FUEL RODS                 =    7
     TYPE OF LATTICE                     =    SQUARE
     GEOMETRICAL CONFIGURATION NUMBER    =    7
     NUMBER OF ISOTOPS                   =    7

     RADIUS FUEL ROD                     =   1.259999
     RADIUS CANNING                      =   1.375000
     DISTANCE BETWEEN RODS               =   2.950000
     PITCH                               =  23.500000
     RADIUS INT. OF PRESS. TUBE          =   4.549999
     RADIUS EXT. OF PRESS. TUBE          =   4.750000
     RADIUS INT. OF CAL. TUBE            =   5.049999
     RADIUS EXT. OF CAL. TUBE            =   5.200000

     TOTAL VOLUME OF THE FILLER          =   0.0
     FILLER VOLUME INT. RUBBER BAND      =   0.0
     FILLER VOLUME IN THE CENTRAL REG.=      0.0
```

ATOMIC DENSITIES, TEMPERATURES, DENSITY FUEL, PURITY D2O AND VOLUMES OF PURE MATERIALS

	FUEL 1	FUEL 2	FUEL 3	CANNING	COOLANT	FILLER	PR. TUBE	INS. LAYER	CAL. TUBE	MODERATOR
TEM.(C)	27	27	27	27	27	27	27	27	27	27
DENSITY	1.3540E 01									
12001	0.0	0.0	0.0	0.0	3.8616E-02	0.0	0.0	0.0	0.0	1.7932E-04
10012	3.2620E-02	3.2620E-02	0.0	0.0	4.6340E-02	0.0	0.0	0.0	0.0	0.0
235	2.3291E-04	2.3291E-04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
238	3.2387E-02	3.2387E-02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10016	0.0	0.0	0.0	0.0	2.7624E-03	0.0	0.0	0.0	0.0	3.3207E-02
27	0.0	0.0	0.0	5.2727E-02	0.0	0.0	6.0293E-02	0.0	6.0293E-02	0.0
12002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.6234E-02
PART.V.	4.9876E 00	4.9876E 00	0.0	9.5199E-01	2.3462E 01	0.0	5.8434E 00	9.2363E 00	4.8302E 00	4.6730E 02
TOT.V.	4.9876E 00	2.9925E 01	0.0	6.6639E 00	2.3462E 01	0.0	5.8434E 00	9.2363E 00	4.8302E 00	4.6730E 02

ISOTOPES WITH RESONANCE ABSORPTION 235 238

2) THERMAL PARAMETERS

A) SPECTRUM CALCULATION (THERMOS)

SPACE POINTS= 5
GROUPS= 30
MIXTURES= 5
ENERGY CUTOFF INDEX = 30

ISOTOPE	CONC MIX 1	CONC MIX 2	CONC MIX 3	CONC MIX 4	CONC MIX 5
USED IN CELL					
12001- 27	8.18276E-03	8.18276E-03	8.18276E-03	1.47335E-02	1.79320E-04
10012- 27	3.14069E-02	3.14069E-02	3.14069E-02	1.76805E-02	0.0
235- 27	1.54136E-04	1.54136E-04	1.54136E-04	0.0	0.0
238- 27	2.14332E-02	2.14332E-02	2.14332E-02	0.0	0.0
10016- 27	5.85355E-04	5.85355E-04	5.85355E-04	1.05396E-03	3.32070E-02
27- 27	6.66024E-03	6.66024E-03	6.66024E-03	1.99904E-02	0.0
12002- 27	0.0	0.0	0.0	0.0	6.62340E-02
REGION NO	1	2	3	4	5
MIXTURE NO	1	2	3	4	5

CYLINDRICAL GEOMETRY - NO LEAKAGE

REGION	THICKNESS	POINT	VOLUME	R(CENTER)	R(INNER)
1	1.54886E 00	1	7.53656E 00	0.0	0.0
2	1.27452E 00	2	1.75065E 01	2.18612E 00	1.54886E 00
3	1.27452E 00	3	2.77129E 01	3.46064E 00	2.82338E 00
4	1.10210E 00	4	3.21926E 01	4.64895E 00	4.09790E 00
5	8.05846E 00	5	4.67301E 02	9.22923E 00	5.20000E 00

THERMAL FLUX SPECTRUM (K,I,N(K,I))

1	1	3.6587E-03	1	2	1.3732E-02	1	3	2.3002E-02	1	4	3.3847E-02	1	5	4.1620E-02
1	6	4.5048E-02	1	7	4.4098E-02	1	8	3.2293E-02	1	9	2.1851E-02	1	10	1.1454E-02
1	11	3.7225E-03	1	12	2.0802E-03	1	13	1.6259E-03	1	14	1.4200E-03	1	15	1.2363E-03
1	16	1.0681E-03	1	17	8.1766E-04	1	18	6.1226E-04	1	19	5.0118E-04	1	20	4.8458E-04
1	21	4.7233E-04	1	22	4.6112E-04	1	23	4.4025E-04	1	24	4.3322E-04	1	25	4.2694E-04
1	26	4.1658E-04	1	27	3.9207E-04	1	28	3.8778E-04	1	29	3.5955E-04	1	30	2.6897E-04
2	1	5.9383E-03	2	2	2.2575E-02	2	3	3.6617E-02	2	4	5.1989E-02	2	5	6.1447E-02
2	6	6.4562E-02	2	7	6.0517E-02	2	8	4.2635E-02	2	9	2.7941E-02	2	10	1.4044E-02
2	11	4.1730E-03	2	12	2.1914E-03	2	13	1.6788E-03	2	14	1.4507E-03	2	15	1.2515E-03
2	16	1.0720E-03	2	17	8.1542E-04	2	18	6.0795E-04	2	19	4.9612E-04	2	20	4.7919E-04
2	21	4.6701E-04	2	22	4.5592E-04	2	23	4.3551E-04	2	24	4.2835E-04	2	25	4.2194E-04
2	26	4.1131E-04	2	27	3.8665E-04	2	28	3.8050E-04	2	29	3.5207E-04	2	30	2.6416E-04
3	1	1.1032E-02	3	2	4.0992E-02	3	3	6.3796E-02	3	4	8.5936E-02	3	5	9.7430E-02
3	6	9.9266E-02	3	7	8.8827E-02	3	8	6.0100E-02	3	9	3.8185E-02	3	10	1.8427E-02
3	11	5.0502E-03	3	12	2.4966E-03	3	13	1.8734E-03	3	14	1.5965E-03	3	15	1.3584E-03
3	16	1.1476E-03	3	17	8.6391E-04	3	18	6.3961E-04	3	19	5.1978E-04	3	20	5.0112E-04
3	21	4.8837E-04	3	22	4.7688E-04	3	23	4.5613E-04	3	24	4.4834E-04	3	25	4.4130E-04
3	26	4.2953E-04	3	27	4.0294E-04	3	28	3.9241E-04	3	29	3.6115E-04	3	30	2.7087E-04
4	1	2.9380E-02	4	2	9.4438E-02	4	3	1.3200E-01	4	4	1.6096E-01	4	5	1.7053E-01
4	6	1.6558E-01	4	7	1.3866E-01	4	8	8.9072E-02	4	9	5.4634E-02	4	10	2.5048E-02
4	11	6.3281E-03	4	12	2.9383E-03	4	13	2.1593E-03	4	14	1.8041E-03	4	15	1.5024E-03
4	16	1.2402E-03	4	17	9.1908E-04	4	18	6.7383E-04	4	19	5.4593E-04	4	20	5.2451E-04
4	21	5.1140E-04	4	22	4.9997E-04	4	23	4.8032E-04	4	24	4.7167E-04	4	25	4.6375E-04
4	26	4.5024E-04	4	27	4.2181E-04	4	28	4.0151E-04	4	29	3.6497E-04	4	30	2.7500E-04
5	1	4.3901E-02	5	2	1.3345E-01	5	3	1.8493E-01	5	4	2.2280E-01	5	5	2.3286E-01
5	6	2.2389E-01	5	7	1.8442E-01	5	8	1.1675E-01	5	9	7.0537E-02	5	10	3.1959E-02
5	11	7.7216E-03	5	12	3.4397E-03	5	13	2.4950E-03	5	14	2.0607E-03	5	15	1.6875E-03
5	16	1.3641E-03	5	17	9.8850E-04	5	18	7.2794E-04	5	19	5.7913E-04	5	20	5.5862E-04
5	21	5.4624E-04	5	22	5.3499E-04	5	23	5.1112E-04	5	24	5.0186E-04	5	25	4.9314E-04
5	26	4.7757E-04	5	27	4.4146E-04	5	28	4.1139E-04	5	29	3.7395E-04	5	30	2.8749E-04

ITCNT= 32 RENORM= 9.99993E-01 EPSA= 4.50467E-06 EPS= 1.00000E-04
LARGEST RES= 4.23193E-06 MEAN RES= 1.64495E-07 N(V*)= 2.21353E-04

POINT	REG	MIX	AVE V
1	1	1	1.60991
2	1	1	1.49815
3	1	1	1.39653
4	2	2	1.26814
5	3	3	1.23318

V AVE 1.24252

MICROSCOPIC CROSS SECTIONS
(WITHOUT TRANSPORT CORRECTION)

		ABSORPTION	NU-FISSION	TRANSPORT	SCATTERING	TOTAL
REGION 1						
12001-	27	2.0622E-01	0.0	2.0160E 01	3.3296E 01	3.3502E 01
10012-	27	2.1119E-03	0.0	4.5481E 00	4.9028E 00	4.9050E 00
235-	27	3.9515E 02	8.1621E 02	2.2501E 02	1.6888E 01	4.1203E 02
238-	27	1.6833E 00	0.0	1.2329E 01	1.0750E 01	1.2433E 01
10016-	27	1.1057E-04	0.0	3.5606E 00	3.8065E 00	3.8066E 00
27-	27	1.4970E-01	0.0	1.5218E 00	1.4692E 00	1.6189E 00
12002-	27	2.8580E-04	0.0	3.3684E 00	4.3347E 00	4.3350E 00
REGION 2						
12001-	27	2.2161E-01	0.0	2.1720E 01	3.4721E 01	3.4942E 01
10012-	27	2.2695E-03	0.0	4.5635E 00	4.9152E 00	4.9175E 00
235-	27	4.2882E 02	8.8655E 02	2.5515E 02	1.7003E 01	4.4582E 02
238-	27	1.8089E 00	0.0	1.2449E 01	1.0750E 01	1.2559E 01
10016-	27	1.1881E-04	0.0	3.5699E 00	3.8135E 00	3.8136E 00
27-	27	1.6086E-01	0.0	1.5348E 00	1.4706E 00	1.6314E 00
12002-	27	3.0711E-04	0.0	3.4882E 00	4.4387E 00	4.4390E 00
REGION 3						
12001-	27	2.3773E-01	0.0	2.3394E 01	3.6208E 01	3.6446E 01
10012-	27	2.4346E-03	0.0	4.5814E 00	4.9294E 00	4.9318E 00
235-	27	4.6443E 02	9.6079E 02	2.9019E 02	1.7108E 01	4.8154E 02
238-	27	1.9405E 00	0.0	1.2575E 01	1.0750E 01	1.2691E 01
10016-	27	1.2746E-04	0.0	3.5808E 00	3.8216E 00	3.8218E 00
27-	27	1.7257E-01	0.0	1.5484E 00	1.4722E 00	1.6448E 00
12002-	27	3.2944E-04	0.0	3.6136E 00	4.5468E 00	4.5471E 00
REGION 4						
12001-	27	2.6180E-01	0.0	2.5640E 01	3.8216E 01	3.8478E 01
10012-	27	2.6811E-03	0.0	4.6131E 00	4.9546E 00	4.9573E 00
235-	27	5.1830E 02	1.0726E 03	3.3870E 02	1.7220E 01	5.3552E 02
238-	27	2.1370E 00	0.0	1.2755E 01	1.0750E 01	1.2887E 01
10016-	27	1.4036E-04	0.0	3.6002E 00	3.8364E 00	3.8365E 00
27-	27	1.9004E-01	0.0	1.5687E 00	1.4753E 00	1.6653E 00
12002-	27	3.6278E-04	0.0	3.7864E 00	4.6972E 00	4.6976E 00
REGION 5						
12001-	27	2.6922E-01	0.0	2.6534E 01	3.8938E 01	3.9207E 01
10012-	27	2.7571E-03	0.0	4.6224E 00	4.9621E 00	4.9648E 00
235-	27	5.3479E 02	1.1069E 03	3.6121E 02	1.7262E 01	5.5205E 02

238-	27	2.1975E 00	0.0	1.2812E 01	1.0750E 01	1.2948E 01
10016-	27	1.4434E-04	0.0	3.6059E 00	3.8407E 00	3.8409E 00
27-	27	1.9543E-01	0.0	1.5751E 00	1.4762E 00	1.6716E 00
12002-	27	3.7306E-04	0.0	3.8465E 00	4.7477E 00	4.7481E 00

B) SPATIAL CALCULATIONS (THEMIS)

MACROSCOPIC CROSS SECTIONS

RING NUMBER	EXTERNAL RADIUS	M.F.P.	SOURCES	TOTAL	ABSORPTION	CROSS SECTIONS DIFFUSION	NU-FISSION	ABSORPTION(FUEL)
1	1.2600	1.6665E 00	8.2232E-04	6.5864E-01	1.4662E-01	5.1202E-01	1.9010E-01	1.4655E-01
2	1.3750	1.2462E 01	3.4407E-05	8.5361E-02	7.8931E-03	7.7468E-02	0.0	0.0
3	1.5489	1.0009E 00	9.1655E-03	1.5315E 00	8.0617E-03	1.5235E 00	0.0	0.0
4	4.0979	1.4928E 00	6.3708E-02	8.2986E-01	1.1217E-01	7.1768E-01	1.4232E-01	1.0876E-01
5	4.5500	8.2383E-01	8.3923E-02	1.7262E 00	1.0234E-02	1.7160E 00	0.0	0.0
6	4.7500	1.0573E 01	3.0587E-04	1.0041E-01	1.1458E-02	8.8950E-02	0.0	0.0
7	5.0500	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	5.2000	1.0573E 01	2.5565E-04	1.0041E-01	1.1458E-02	8.8950E-02	0.0	0.0
9	6.5361	2.6367E 00	7.7090E-02	4.4906E-01	7.7779E-05	4.4898E-01	0.0	0.0
MODERATOR		2.6367E 00	6.8796E-01	3.7927E-01	7.7779E-05	4.4898E-01		

DISADVANTAGE FACTOR FOR CANNING = 1.0803E 00
DISADVANTAGE FACTOR FOR COOLANT = 1.1437E 00

RING NUMBER	FLUX
1	1.0000E 00
2	1.0789E 00
3	1.1434E 00
4	1.3831E 00
5	2.0966E 00
6	2.4222E 00
7	2.4535E 00
8	2.4848E 00
9	2.6887E 00
MODERATOR	3.2250E 00

SPATIAL FLUX DISTRIBUTION IN MODERATOR

DISTANCE FROM CENTER	FLUX
6.5361E 00	2.7525E 00
7.2084E 00	2.8659E 00
7.8806E 00	2.9672E 00
8.5528E 00	3.0582E 00
9.2251E 00	3.1403E 00
9.8973E 00	3.2145E 00
1.0570E 01	3.2819E 00
1.1242E 01	3.3430E 00
1.1914E 01	3.3985E 00
1.2586E 01	3.4489E 00
1.3258E 01	3.4947E 00

ROD BLACKNESS = 1.9554E-01
THERMAL UTILISATION FACTOR = 8.9172E-01
THERMAL MULTIPLICATION FACTOR = 1.1658E 00
DIFFUSION COEFFICIENT = 8.6764E-01
DIFFUSION AREA = 1.6695E 02
TH. NEUT. LIFETIME(CRIT.CORE) = 6.6703E-04

3) EPITHERMAL PARAMETERS

** SANCOFF COEFFICIENT CALCULATION (SHOCK-II)

TOTAL CROSS SECTIONS

CANNING	7.3818E-02
COOLANT	1.0141E 00

MATRIX OF GROUPS OF SYMMETRY

RODS	1	2	3	4	5	6	7
1	0	1	2	3	2	1	4
2	1	0	1	2	3	2	4
3	2	1	0	1	2	3	4
4	3	2	1	0	1	2	4
5	2	3	2	1	0	1	4
6	1	2	3	2	1	0	4
7	4	4	4	4	4	4	0

COUPLES TO BE CONSIDERED

ROD N. 1 WITH RODS N. 2- 3- 4- 7-

DANCOFF COEFFICIENTS FOR EVERY GROUP OF SYMMETRY

RODS I	J	GROUP SYMMETRY	DANCOFF COEFF.
1	2	1	0.85425019E-01
1	3	2	0.10307513E-02
1	4	3	0.0
1	7	4	0.85425019E-01

DANCOFF COEFFICIENTS FOR EVERY ROD WITH RESPECT TO ALL OTHERS

ROD	DANCOFF COEFF.
1	0.25833654E 00
2	0.25833654E 00
3	0.25833654E 00
4	0.25833654E 00
5	0.25833654E 00
6	0.25833654E 00
7	0.51255012E 00

FOR THE FUEL IN THE CLUSTER

TOTAL 0.29465252E 00

B) RESONANCE ESCAPE PROBABILITY, FISSION FACTOR AND SLOWING DOWN AREA CALCULATION (PETARD)

REGION	RADIUS	SPAT.SOURCE DIS.
1	1.2600	0.1000E 01
2	1.3750	0.0
3	1.5489	0.0
4	4.0979	0.1000E 01
5	4.5500	0.0
6	4.7500	0.0
7	5.0500	0.0
8	5.2000	0.0
9	6.5361	0.0
10	8.7769	0.0
11	11.0177	0.0
12	13.2585	0.0

SQUARE ROOT S/M = 2.8341E-01

GROUP		1	2	3	4	5	6	7	8	9
LET.WID.		2.0000E 00	2.5000E 00	1.2500E 00	3.5000E 00	2.0000E 00	9.9998E-01	5.0000E-01	1.0000E 00	1.5000E 00
SOUR.SP.		5.7333E-01	4.1130E-01	1.5365E-02						
235 RESONANCE INTEGRALS										
ABSORPTION										
REG.FUEL	1	0.0	0.0	0.0	0.0	0.0	0.0	1.9851E 01	7.0273E 01	6.4801E 01
	2	0.0	0.0	0.0	0.0	0.0	0.0	1.9851E 01	7.0273E 01	6.4801E 01
FISSION										
REG.FUEL	1	0.0	0.0	0.0	0.0	0.0	0.0	2.3384E 01	7.4344E 01	8.1628E 01
	2	0.0	0.0	0.0	0.0	0.0	0.0	2.3384E 01	7.4344E 01	8.1628E 01
A(238)		0.0	0.0	4.1200E-01	1.6728E 00	7.2872E-01	4.9770E-01	3.3953E-01	2.6827E-01	2.0763E-01
B(238)		0.0	0.0	0.0	1.2676E 00	2.8884E 00	2.3566E 00	3.4477E 00	4.4082E 00	1.0186E 01

MACROSCOPIC CROSS SECTIONS

NU-FISSION

GROUP	1	2	3	4	5	6	7	8	9
REGION 1	4.9377E-02	1.2963E-03	0.0	0.0	0.0	0.0	1.0892E-02	1.7316E-02	1.2675E-02
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	3.2677E-02	8.5789E-04	0.0	0.0	0.0	0.0	7.2084E-03	1.1459E-02	8.3880E-03
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TOTAL TRANSPORT

REGION 1	1.9434E-01	3.4153E-01	4.9888E-01	5.1331E-01	5.2079E-01	5.3387E-01	5.9093E-01	5.6158E-01	5.7289E-01
2	1.0497E-01	1.8914E-01	3.0671E-01	7.6022E-02	7.3027E-02	7.3160E-02	7.3552E-02	7.3556E-02	7.4656E-02
3	1.3374E-01	2.8903E-01	4.7151E-01	4.8374E-01	4.7722E-01	4.7791E-01	4.7923E-01	4.7934E-01	4.8647E-01
4	1.7021E-01	3.1116E-01	4.6880E-01	4.5181E-01	4.5500E-01	4.6381E-01	5.0191E-01	4.8251E-01	4.9165E-01
5	1.3374E-01	2.8903E-01	4.7151E-01	4.8374E-01	4.7722E-01	4.7791E-01	4.7923E-01	4.7934E-01	4.8647E-01
6	1.2003E-01	2.1628E-01	3.5073E-01	8.6931E-02	8.3506E-02	8.3658E-02	8.4107E-02	8.4111E-02	8.5369E-02
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	1.2003E-01	2.1628E-01	3.5073E-01	8.6931E-02	8.3506E-02	8.3658E-02	8.4107E-02	8.4111E-02	8.5369E-02
9	1.3838E-01	2.9228E-01	2.6403E-01	2.6595E-01	2.6922E-01	2.6913E-01	2.6914E-01	2.6915E-01	2.6916E-01
10	1.3838E-01	2.9228E-01	2.6403E-01	2.6595E-01	2.6922E-01	2.6913E-01	2.6914E-01	2.6915E-01	2.6916E-01
11	1.3838E-01	2.9228E-01	2.6403E-01	2.6595E-01	2.6922E-01	2.6913E-01	2.6914E-01	2.6915E-01	2.6916E-01
12	1.3838E-01	2.9228E-01	2.6403E-01	2.6595E-01	2.6922E-01	2.6913E-01	2.6914E-01	2.6915E-01	2.6916E-01

TRANSFER I-TH

REGION 1	0.0	0.0	2.8285E-10	0.0	0.0	0.0	0.0	0.0	1.7665E-02
2	8.6451E-11	6.5524E-10	0.0	0.0	0.0	0.0	0.0	0.0	3.6828E-03
3	1.0271E-07	2.9077E-06	2.4797E-05	5.1576E-04	6.1515E-03	2.4617E-02	5.0738E-02	1.1101E-01	4.3872E-01
4	2.1774E-08	6.1623E-07	5.2546E-06	1.0929E-04	1.3035E-03	5.2162E-03	1.0751E-02	2.3524E-02	1.0512E-01
5	1.0271E-07	2.9077E-06	2.4797E-05	5.1575E-04	6.1515E-03	2.4617E-02	5.0738E-02	1.1101E-01	4.3872E-01
6	9.8856E-11	7.4926E-10	0.0	0.0	0.0	0.0	0.0	0.0	4.2113E-03
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	9.8856E-11	7.4926E-10	0.0	0.0	0.0	0.0	0.0	0.0	4.2113E-03
9	4.7937E-10	1.3503E-08	1.1515E-07	2.3950E-06	2.8566E-05	1.1431E-04	2.3561E-04	9.2663E-03	1.1473E-01
10	4.7937E-10	1.3503E-08	1.1515E-07	2.3950E-06	2.8566E-05	1.1431E-04	2.3561E-04	9.2663E-03	1.1473E-01
11	4.7937E-10	1.3503E-08	1.1515E-07	2.3950E-06	2.8566E-05	1.1431E-04	2.3561E-04	9.2663E-03	1.1473E-01

	12	4.7937E-10	1.3503E-08	1.1515E-07	2.3950E-06	2.8566E-05	1.1431E-04	2.3561E-04	9.2663E-03	1.1473E-01

RESONANCE

REGION	1	0.0	0.0	1.0675E-02	1.8803E-02	2.5056E-02	3.7751E-02	9.4529E-02	6.5518E-02	7.6875E-02
	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	4	0.0	0.0	7.0644E-03	1.2444E-02	1.6582E-02	2.4983E-02	6.2558E-02	4.3359E-02	5.0875E-02
	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

OUTSCATTERING

REGION	1	7.9051E-02	1.4623E-02	2.3628E-02	8.1236E-03	1.3474E-02	2.6872E-02	5.5067E-02	2.6585E-02	1.7665E-02
	2	2.2451E-02	8.5165E-03	4.1836E-02	1.5299E-03	2.7049E-03	5.4161E-03	1.0839E-02	5.4172E-03	3.6828E-03
	3	7.0350E-02	1.5001E-01	3.5856E-01	2.1815E-01	3.5369E-01	5.3011E-01	6.8952E-01	5.3321E-01	4.3872E-01
	4	7.0057E-02	4.2540E-02	9.6900E-02	5.1794E-02	8.4205E-02	1.3080E-01	1.8392E-01	1.3126E-01	1.0512E-01
	5	7.0350E-02	1.5001E-01	3.5856E-01	2.1815E-01	3.5369E-01	5.3011E-01	6.8952E-01	5.3321E-01	4.3872E-01
	6	2.5673E-02	9.7385E-03	4.7839E-02	1.7494E-03	3.0930E-03	6.1933E-03	1.2394E-02	6.1945E-03	4.2113E-03
	7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8	2.5673E-02	9.7385E-03	4.7839E-02	1.7494E-03	3.0930E-03	6.1933E-03	1.2394E-02	6.1945E-03	4.2113E-03
	9	9.1512E-02	8.0991E-02	1.2988E-01	5.1314E-02	9.0216E-02	1.4900E-01	2.0357E-01	1.4902E-01	1.1473E-01
	10	9.1512E-02	8.0991E-02	1.2988E-01	5.1314E-02	9.0216E-02	1.4900E-01	2.0357E-01	1.4902E-01	1.1473E-01
	11	9.1512E-02	8.0991E-02	1.2988E-01	5.1314E-02	9.0216E-02	1.4900E-01	2.0357E-01	1.4902E-01	1.1473E-01
	12	9.1512E-02	8.0991E-02	1.2988E-01	5.1314E-02	9.0216E-02	1.4900E-01	2.0357E-01	1.4902E-01	1.1473E-01

ABSORPTION

REGION	1	1.8597E-02	5.7289E-03	1.0675E-02	1.8804E-02	2.5057E-02	3.7753E-02	9.4533E-02	6.5522E-02	7.6884E-02
	2	4.2293E-04	9.6200E-05	3.1983E-04	1.1010E-04	0.0	1.3170E-04	5.2726E-04	5.2726E-04	8.7848E-04
	3	5.0327E-05	5.0246E-08	1.1891E-07	3.0558E-05	1.1256E-04	2.3493E-04	3.3292E-04	4.8954E-04	9.3308E-04
	4	1.2371E-02	3.8035E-03	7.1049E-03	1.2464E-02	1.6606E-02	2.5051E-02	6.2697E-02	4.3532E-02	5.1190E-02
	5	5.0327E-05	5.0246E-08	1.1891E-07	3.0558E-05	1.1256E-04	2.3493E-04	3.3292E-04	4.8954E-04	9.3308E-04
	6	4.8362E-04	1.1000E-04	3.6572E-04	1.2590E-04	0.0	1.5060E-04	6.0292E-04	6.0292E-04	1.0045E-03
	7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8	4.8362E-04	1.1000E-04	3.6572E-04	1.2590E-04	0.0	1.5060E-04	6.0292E-04	6.0292E-04	1.0045E-03
	9	6.0477E-04	0.0	0.0	1.3989E-07	5.1535E-07	1.0758E-06	1.5242E-06	2.2413E-06	4.2725E-06
	10	6.0477E-04	0.0	0.0	1.3989E-07	5.1535E-07	1.0758E-06	1.5242E-06	2.2413E-06	4.2725E-06
	11	6.0477E-04	0.0	0.0	1.3989E-07	5.1535E-07	1.0758E-06	1.5242E-06	2.2413E-06	4.2725E-06
	12	6.0477E-04	0.0	0.0	1.3989E-07	5.1535E-07	1.0758E-06	1.5242E-06	2.2413E-06	4.2725E-06

REMOVAL

REGION	1	9.7647E-02	2.0352E-02	3.4303E-02	2.6927E-02	3.8531E-02	6.4625E-02	1.4960E-01	9.2108E-02	9.4549E-02
	2	1.2874E-02	8.6127E-03	4.2156E-02	1.6400E-03	2.7049E-03	5.5478E-03	1.1366E-02	5.9444E-03	4.5613E-03
	3	7.0400E-02	1.5001E-01	3.5856E-01	2.1818E-01	3.5380E-01	5.3035E-01	6.8985E-01	5.3370E-01	4.3966E-01
	4	8.2428E-02	4.6343E-02	1.0401E-01	6.4259E-02	1.0081E-01	1.5585E-01	2.4662E-01	1.7480E-01	1.5631E-01
	5	7.0400E-02	1.5001E-01	3.5856E-01	2.1818E-01	3.5380E-01	5.3035E-01	6.8985E-01	5.3370E-01	4.3966E-01
	6	2.6156E-02	9.8485E-03	4.8205E-02	1.8753E-03	3.0930E-03	6.3439E-03	1.2997E-02	6.7974E-03	5.2158E-03
	7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8	2.6156E-02	9.8485E-03	4.8205E-02	1.8753E-03	3.0930E-03	6.3439E-03	1.2997E-02	6.7974E-03	5.2158E-03
	9	9.2117E-02	8.0991E-02	1.2988E-01	5.1314E-02	9.0217E-02	1.4900E-01	2.0357E-01	1.4903E-01	1.1473E-01
	10	9.2117E-02	8.0991E-02	1.2988E-01	5.1314E-02	9.0217E-02	1.4900E-01	2.0357E-01	1.4903E-01	1.1473E-01
	11	9.2117E-02	8.0991E-02	1.2988E-01	5.1314E-02	9.0217E-02	1.4900E-01	2.0357E-01	1.4903E-01	1.1473E-01
	12	9.2117E-02	8.0991E-02	1.2988E-01	5.1314E-02	9.0217E-02	1.4900E-01	2.0357E-01	1.4903E-01	1.1473E-01

SOURCES

REGION	1	7.3623E-02	5.2816E-02	1.9731E-03
	2	0.0	0.0	0.0
	3	0.0	0.0	0.0
	4	4.9971E-01	3.5848E-01	1.3392E-02
	5	0.0	0.0	0.0
	6	0.0	0.0	0.0
	7	0.0	0.0	0.0
	8	0.0	0.0	0.0
	9	0.0	0.0	0.0
	10	0.0	0.0	0.0
	11	0.0	0.0	0.0
	12	0.0	0.0	0.0

FLUXES

REGION	1	6.1366E-02	9.8222E-02	2.3791E-02	3.8016E-02	1.8423E-02	8.3570E-03	3.4355E-03	6.9264E-03	9.3333E-03
	2	5.6361E-02	8.9880E-02	2.3290E-02	3.8935E-02	1.8819E-02	8.5993E-03	3.6822E-03	7.2572E-03	9.8137E-03
	3	5.5338E-02	8.6843E-02	2.3106E-02	3.8981E-02	1.8927E-02	8.6735E-03	3.7556E-03	7.3680E-03	9.9833E-03
	4	4.9318E-02	7.6451E-02	2.0969E-02	3.7869E-02	1.8934E-02	8.7976E-03	3.8819E-03	7.6825E-03	1.0574E-02
	5	3.1084E-02	5.1904E-02	1.7772E-02	3.7258E-02	1.9416E-02	9.2640E-03	4.3820E-03	8.5510E-03	1.2066E-02
	6	2.6108E-02	4.6128E-02	1.6829E-02	3.7396E-02	1.9446E-02	9.3348E-03	4.4690E-03	8.7312E-03	1.2429E-02
	7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8	2.2383E-02	4.2503E-02	1.6429E-02	3.7485E-02	1.9477E-02	9.3637E-03	4.5011E-03	8.7989E-03	1.2568E-02
	9	1.7031E-02	3.4940E-02	1.5799E-02	3.6726E-02	1.9438E-02	9.4102E-03	4.5704E-03	8.9546E-03	1.2892E-02
	10	1.0488E-02	2.3735E-02	1.3253E-02	3.4863E-02	1.9169E-02	9.4232E-03	4.6425E-03	9.1551E-03	1.3354E-02
	11	7.1410E-03	1.6973E-02	1.0956E-02	3.2815E-02	1.8754E-02	9.3581E-03	4.6529E-03	9.2365E-03	1.3608E-02
	12	6.3127E-03	1.4529E-02	9.9377E-03	3.1765E-02	1.8511E-02	9.3065E-03	4.6445E-03	9.2503E-03	1.3689E-02

TRANSFER KERNEL

REGION 1

GROUP	1	1.2584E-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

2	9.6178E-02	3.2171E-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	3.6364E-03	1.4602E-02	4.6458E-01	0.0	0.0	0.0	0.0	0.0	0.0
4	3.0825E-04	4.0113E-05	2.3609E-02	4.8639E-01	0.0	0.0	0.0	0.0	0.0
5	3.0752E-07	5.7014E-07	1.6346E-05	8.1236E-03	4.8226E-01	0.0	0.0	0.0	0.0
6	4.0483E-09	4.0366E-08	1.3935E-06	3.5598E-10	1.3474E-02	4.6924E-01	0.0	0.0	0.0
7	5.9466E-11	4.0268E-10	5.4883E-10	2.4674E-11	0.0	2.6872E-02	4.4133E-01	0.0	0.0
8	5.7946E-11	0.0	8.6887E-09	9.9697E-11	0.0	0.0	5.5067E-02	4.6947E-01	0.0
9	6.8959E-12	0.0	6.8140E-09	0.0	0.0	0.0	0.0	2.6585E-02	4.7834E-01
10	0.0	0.0	2.8285E-10	0.0	0.0	0.0	0.0	0.0	1.7665E-02

REGION 2

GROUP 1	8.2096E-02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	2.1529E-02	1.8053E-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	6.6963E-04	8.3356E-03	2.6456E-01	0.0	0.0	0.0	0.0	0.0	0.0
4	2.4949E-04	1.7704E-04	4.1836E-02	7.4382E-02	0.0	0.0	0.0	0.0	0.0
5	2.5006E-06	3.3397E-06	0.0	1.5299E-03	7.0322E-02	0.0	0.0	0.0	0.0
6	1.0082E-07	1.0307E-07	0.0	0.0	2.7049E-03	6.7612E-02	0.0	0.0	0.0
7	1.1284E-08	2.0416E-08	0.0	0.0	0.0	5.4161E-03	6.2186E-02	0.0	0.0
8	7.2568E-09	1.9893E-08	0.0	0.0	0.0	0.0	1.0839E-02	6.7612E-02	0.0
9	3.2809E-09	7.9892E-09	0.0	0.0	0.0	0.0	0.0	5.4172E-03	7.0095E-02
10	8.6451E-11	6.5524E-10	0.0	0.0	0.0	0.0	0.0	0.0	3.6828E-03

REGION 3

GROUP 1	6.3340E-02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	6.5541E-02	1.3902E-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	3.4327E-03	1.1117E-01	1.1294E-01	0.0	0.0	0.0	0.0	0.0	0.0
4	1.3352E-03	3.7674E-02	3.4856E-01	2.6557E-01	0.0	0.0	0.0	0.0	0.0
5	3.5850E-05	1.0143E-03	8.6496E-03	1.8999E-01	1.2342E-01	0.0	0.0	0.0	0.0
6	3.5456E-06	1.0036E-04	8.5581E-04	1.7800E-02	2.3013E-01	-5.2438E-02	0.0	0.0	0.0
7	8.1179E-07	2.2980E-05	1.9597E-04	4.0759E-03	4.8618E-02	2.3022E-01	-2.1060E-01	0.0	0.0
8	7.9101E-07	2.2392E-05	1.9096E-04	3.9717E-03	4.7374E-02	1.8957E-01	4.6211E-01	-5.4348E-02	0.0
9	3.5761E-07	1.0124E-05	8.6334E-05	1.7957E-03	2.1418E-02	8.5708E-02	1.7665E-01	4.2219E-01	4.6818E-02
10	1.0271E-07	2.9077E-06	2.4797E-05	5.1576E-04	6.1515E-03	2.4617E-02	5.0738E-02	1.1101E-01	4.3872E-01

REGION 4

GROUP 1	1.0707E-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	8.0256E-02	2.6516E-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	3.2185E-03	3.4272E-02	3.6480E-01	0.0	0.0	0.0	0.0	0.0	0.0
4	5.1843E-04	8.0320E-03	9.4768E-02	3.8755E-01	0.0	0.0	0.0	0.0	0.0
5	8.1159E-06	2.1573E-04	1.8437E-03	4.5828E-02	3.5419E-01	0.0	0.0	0.0	0.0
6	7.6672E-07	2.1305E-05	1.8227E-04	3.7718E-03	5.8022E-02	3.0797E-01	0.0	0.0	0.0
7	1.7348E-07	4.8724E-06	4.1526E-05	8.6368E-04	1.0302E-02	6.7251E-02	2.5530E-01	0.0	0.0
8	1.6857E-07	4.7474E-06	4.0469E-05	8.4159E-04	1.0039E-02	4.0169E-02	1.3573E-01	3.0771E-01	0.0
9	7.6196E-08	2.1463E-06	1.8299E-05	3.8051E-04	4.5385E-03	1.8161E-02	3.7433E-02	1.0774E-01	3.3534E-01
10	2.1774E-08	6.1623E-07	5.2546E-06	1.0929E-04	1.3035E-03	5.2162E-03	1.0751E-02	2.3524E-02	1.0512E-01

REGION 5

GROUP 1	6.3340E-02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

2	6.5541E-02	1.3902E-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	3.4327E-03	1.1117E-01	1.1294E-01	0.0	0.0	0.0	0.0	0.0	0.0
4	1.3352E-03	3.7674E-02	3.4856E-01	2.6557E-01	0.0	0.0	0.0	0.0	0.0
5	3.5850E-05	1.0143E-03	8.6496E-03	1.8999E-01	1.2341E-01	0.0	0.0	0.0	0.0
6	3.5456E-06	1.0036E-04	8.5581E-04	1.7800E-02	2.3013E-01	-5.2438E-02	0.0	0.0	0.0
7	8.1179E-07	2.2980E-05	1.9597E-04	4.0759E-03	4.8618E-02	2.3022E-01	-2.1060E-01	0.0	0.0
8	7.9101E-07	2.2392E-05	1.9096E-04	3.9717E-03	4.7374E-02	1.8957E-01	4.6211E-01	-5.4348E-02	0.0
9	3.5761E-07	1.0124E-05	8.6334E-05	1.7957E-03	2.1418E-02	8.5708E-02	1.7665E-01	4.2219E-01	4.6818E-02
10	1.0271E-07	2.9077E-06	2.4797E-05	5.1575E-04	6.1515E-03	2.4617E-02	5.0738E-02	1.1101E-01	4.3872E-01

REGION 6

GROUP 1	9.3876E-02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	2.4619E-02	2.0643E-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	7.6572E-04	9.5317E-03	3.0252E-01	0.0	0.0	0.0	0.0	0.0	0.0
4	2.8529E-04	2.0245E-04	4.7839E-02	8.5055E-02	0.0	0.0	0.0	0.0	0.0
5	2.8594E-06	3.8190E-06	0.0	1.7494E-03	8.0413E-02	0.0	0.0	0.0	0.0
6	1.1529E-07	1.1785E-07	0.0	0.0	3.0930E-03	7.7314E-02	0.0	0.0	0.0
7	1.2903E-08	2.3345E-08	0.0	0.0	0.0	6.1933E-03	7.1109E-02	0.0	0.0
8	8.2981E-09	2.2748E-08	0.0	0.0	0.0	0.0	1.2394E-02	7.7314E-02	0.0
9	3.7517E-09	9.1356E-09	0.0	0.0	0.0	0.0	0.0	6.1945E-03	8.0153E-02
10	9.8856E-11	7.4926E-10	0.0	0.0	0.0	0.0	0.0	0.0	4.2113E-03

REGION 7

GROUP 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

REGION 8

GROUP 1	9.3876E-02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	2.4619E-02	2.0643E-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	7.6572E-04	9.5317E-03	3.0252E-01	0.0	0.0	0.0	0.0	0.0	0.0
4	2.8529E-04	2.0245E-04	4.7839E-02	8.5055E-02	0.0	0.0	0.0	0.0	0.0
5	2.8594E-06	3.8190E-06	0.0	1.7494E-03	8.0413E-02	0.0	0.0	0.0	0.0
6	1.1529E-07	1.1785E-07	0.0	0.0	3.0930E-03	7.7314E-02	0.0	0.0	0.0
7	1.2903E-08	2.3345E-08	0.0	0.0	0.0	6.1933E-03	7.1109E-02	0.0	0.0
8	8.2981E-09	2.2748E-08	0.0	0.0	0.0	0.0	1.2394E-02	7.7314E-02	0.0
9	3.7517E-09	9.1356E-09	0.0	0.0	0.0	0.0	0.0	6.1945E-03	8.0153E-02
10	9.8856E-11	7.4926E-10	0.0	0.0	0.0	0.0	0.0	0.0	4.2113E-03

REGION 9

GROUP 1	4.6263E-02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

2	9.1933E-02	2.1129E-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	3.3434E-05	7.3006E-02	1.3415E-01	0.0	0.0	0.0	0.0	0.0	0.0
4	9.4220E-06	7.9786E-03	1.2984E-01	2.1463E-01	0.0	0.0	0.0	0.0	0.0
5	1.8457E-07	4.7102E-06	4.0166E-05	5.1018E-02	1.7901E-01	0.0	0.0	0.0	0.0
6	1.7201E-08	4.6602E-07	3.9741E-06	2.4806E-04	7.3991E-02	1.2013E-01	0.0	0.0	0.0
7	3.8818E-09	1.0671E-07	9.1001E-07	1.8927E-05	1.1509E-02	7.8635E-02	6.5569E-02	0.0	0.0
8	3.7499E-09	1.0398E-07	8.8674E-07	1.8443E-05	4.5896E-03	6.1104E-02	1.5731E-01	1.2012E-01	0.0
9	1.6803E-09	4.7012E-08	4.0091E-07	8.3387E-06	9.9460E-05	9.1475E-03	4.6016E-02	1.3976E-01	1.5443E-01
10	4.7937E-10	1.3503E-08	1.1515E-07	2.3950E-06	2.8566E-05	1.1431E-04	2.3561E-04	9.2663E-03	1.1473E-01

REGION 10

GROUP 1	4.6263E-02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	9.1933E-02	2.1129E-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	3.3434E-05	7.3006E-02	1.3415E-01	0.0	0.0	0.0	0.0	0.0	0.0
4	9.4220E-06	7.9786E-03	1.2984E-01	2.1463E-01	0.0	0.0	0.0	0.0	0.0
5	1.8457E-07	4.7102E-06	4.0166E-05	5.1018E-02	1.7901E-01	0.0	0.0	0.0	0.0
6	1.7201E-08	4.6602E-07	3.9741E-06	2.4806E-04	7.3991E-02	1.2013E-01	0.0	0.0	0.0
7	3.8818E-09	1.0671E-07	9.1001E-07	1.8927E-05	1.1509E-02	7.8635E-02	6.5569E-02	0.0	0.0
8	3.7499E-09	1.0398E-07	8.8674E-07	1.8443E-05	4.5896E-03	6.1104E-02	1.5731E-01	1.2012E-01	0.0
9	1.6803E-09	4.7012E-08	4.0091E-07	8.3387E-06	9.9460E-05	9.1475E-03	4.6016E-02	1.3976E-01	1.5443E-01
10	4.7937E-10	1.3503E-08	1.1515E-07	2.3950E-06	2.8566E-05	1.1431E-04	2.3561E-04	9.2663E-03	1.1473E-01

REGION 11

GROUP 1	4.6263E-02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	9.1933E-02	2.1129E-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	3.3434E-05	7.3006E-02	1.3415E-01	0.0	0.0	0.0	0.0	0.0	0.0
4	9.4220E-06	7.9786E-03	1.2984E-01	2.1463E-01	0.0	0.0	0.0	0.0	0.0
5	1.8457E-07	4.7102E-06	4.0166E-05	5.1018E-02	1.7901E-01	0.0	0.0	0.0	0.0
6	1.7201E-08	4.6602E-07	3.9741E-06	2.4806E-04	7.3991E-02	1.2013E-01	0.0	0.0	0.0
7	3.8818E-09	1.0671E-07	9.1001E-07	1.8927E-05	1.1509E-02	7.8635E-02	6.5569E-02	0.0	0.0
8	3.7499E-09	1.0398E-07	8.8674E-07	1.8443E-05	4.5896E-03	6.1104E-02	1.5731E-01	1.2012E-01	0.0
9	1.6803E-09	4.7012E-08	4.0091E-07	8.3387E-06	9.9460E-05	9.1475E-03	4.6016E-02	1.3976E-01	1.5443E-01
10	4.7937E-10	1.3503E-08	1.1515E-07	2.3950E-06	2.8566E-05	1.1431E-04	2.3561E-04	9.2663E-03	1.1473E-01

REGION 12

GROUP 1	4.6263E-02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	9.1933E-02	2.1129E-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	3.3434E-05	7.3006E-02	1.3415E-01	0.0	0.0	0.0	0.0	0.0	0.0
4	9.4220E-06	7.9786E-03	1.2984E-01	2.1463E-01	0.0	0.0	0.0	0.0	0.0
5	1.8457E-07	4.7102E-06	4.0166E-05	5.1018E-02	1.7901E-01	0.0	0.0	0.0	0.0
6	1.7201E-08	4.6602E-07	3.9741E-06	2.4806E-04	7.3991E-02	1.2013E-01	0.0	0.0	0.0
7	3.8818E-09	1.0671E-07	9.1001E-07	1.8927E-05	1.1509E-02	7.8635E-02	6.5569E-02	0.0	0.0
8	3.7499E-09	1.0398E-07	8.8674E-07	1.8443E-05	4.5896E-03	6.1104E-02	1.5731E-01	1.2012E-01	0.0
9	1.6803E-09	4.7012E-08	4.0091E-07	8.3387E-06	9.9460E-05	9.1475E-03	4.6016E-02	1.3976E-01	1.5443E-0
10	4.7937E-10	1.3503E-08	1.1515E-07	2.3950E-06	2.8566E-05	1.1431E-04	2.3561E-04	9.2663E-03	1.1473E-0

GROUP	RES.ESC.PROB.	MOD.DIF.COFF.	DIFF.COEFF.
1	1.0000E 00	2.4088E 00	2.3120E 00
2	1.0000E 00	1.1405E 00	1.1343E 00
3	9.9226E-01	1.2625E 00	1.1435E 00
4	9.7586E-01	1.2534E 00	1.1880E 00
5	9.8361E-01	1.2381E 00	1.1805E 00
6	9.8833E-01	1.2386E 00	1.1817E 00
7	9.8709E-01	1.2385E 00	1.1794E 00
8	9.8193E-01	1.2385E 00	1.1826E 00
9	9.7018E-01	1.2384E 00	1.1829E 00

TOTAL RESONANCE ESCAPE PROBABILITY = 8.8517E-01

EPITHERMAL MULTIPLICATION FACTOR = 8.8766E-02

FAST MULTIPLICATION FACTOR = 1.0430E 00

4) FAST PARAMETERS

FAST MULTIPLICATION FACTOR CALCULATION (RABBIT)

SOURCE FACTOR = 1.6387E 00

MACROSCOPIC CROSS SECTIONS

	REG.1 (FUEL)		REG.2 (DILUENT)		REG.3 (MODERATOR)		REG.4 (CANNING)		REG.5 (COOLANT)	
	GR.1	GR.2	GR.1	GR.2	GR.1	GR.2	GR.1	GR.2	GR.1	GR.2
NU-FISS.	4.9377E-02	1.2963E-03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TRANSP.	1.9434E-01	3.4153E-01	1.2738E-01	2.6694E-01	1.3535E-01	2.8508E-01	1.0497E-01	1.8914E-01	1.3374E-01	2.8903E-01
I TO I	9.7532E-02	3.2118E-01	6.7489E-02	1.4820E-01	4.6429E-02	2.0718E-01	8.2096E-02	1.8053E-01	6.3340E-02	1.3902E-01
I TO I+1	7.5869E-02	1.4623E-02	5.5806E-02	1.1871E-01	8.8715E-02	7.7894E-02	2.1529E-02	8.5161E-03	6.5541E-02	1.5001E-01
I TO I+2	3.1863E-03	0.0	3.9494E-03	0.0	6.4398E-05	0.0	9.2175E-04	0.0	4.8094E-03	0.0
OUT SC.	7.9051E-02	1.4623E-02	5.9754E-02	1.1871E-01	8.8335E-02	7.7895E-02	2.2451E-02	8.5165E-03	7.0350E-02	1.5001E-01
ABSORPT.	1.8597E-02	5.7289E-03	1.3275E-04	2.1319E-05	5.9065E-04	2.4099E-06	4.2293E-04	9.6200E-05	5.0327E-05	5.0246E-08
					(TUBES)		(MODERATOR)			
REMOVAL	9.7647E-02	2.0351E-02	5.9887E-02	1.1873E-01	1.4022E-02	5.2798E-03	9.2117E-02	8.0991E-02		

VALUES OF THE SOURCE FORM FACTOR

1.0000E 00	1.6387E 00	1.0000E 00	1.6387E 00	1.0000E 00	1.6387E 00	1.0000E 00	1.6387E 00

COLLISION PROBABILITIES IN A CLUSTER

	PFF		PFD		PDF		PDD	
GROUP 1	4.0262E-01	3.9636E-01	1.0821E-01	1.0653E-01	1.9133E-01	1.8836E-01	3.1949E-01	3.1453E-01
GROUP 2	5.2064E-01	5.1297E-01	1.6020E-01	1.5783E-01	2.3753E-01	2.3403E-01	4.4331E-01	4.3677E-01

	PCC		PMM
GROUP 1	5.1083E-01	5.0289E-01	8.9264E-01
GROUP 2	6.8084E-01	6.7080E-01	9.4864E-01

COLLISION PROBABILITIES FOR INCIDENT NEUTRONS

	GC		GM
GROUP 1	7.2703E-01	7.3883E-01	9.9059E-01
GROUP 2	8.9158E-01	9.1962E-01	9.9801E-01

COLLISION PROBABILITIES IN A LATTICE

	PICC		PICM		PIMC	PIMM
GROUP 1	5.1418E-01	5.0635E-01	4.8582E-01	4.9365E-01	7.8254E-02	9.2175E-01

GROUP 2	6.8140E-01	6.7140E-01	3.1860E-01	3.2860E-01	4.5798E-02	9.5420E-01

ANALYTICAL CALCULATION FAST MULTIPLICATION FACTOR

CLUSTER-TO-MODERATOR SOURCE RATIO AT 0.1 MEV = 2.0029E 00

COLLISION DENSITIES

	C F	C D	C M
GROUP 1	3.4076E-01	1.1050E-01	6.1357E-01
GROUP 2	8.4666E-01	3.8288E-01	2.9682E 00

FAST MULTIPLICATION FACTOR = 1.0436E 00

FAST FISSION RATIO = 7.4929E-02

5) CRITICALITY

THERMAL UTILISATION FACTOR	8.9172453E-01
THERMAL FISSION FACTOR	1.3074083E 00
THERMAL MULTIPLICATION FACTOR	1.1658487E 00
RESONANCE ESCAPE PROBABILITY	8.8516855E-01
FAST FISSION FACTOR	1.0436144E 00
INFINITE MULTIPLICATION FACTOR (4-FACTOR FORMULA)	1.0876179E 00
THERMAL DIFFUSION AREA	1.6695007E 02

6) NEUTRON BALANCE

A) FAST RANGE (RABBIT)

I) DETAILED REACTION RATES

GROUP 1

		FLUX	SOURCE IJ	SOURCE II	ABSORPTION	SCATT.OUT	PROD. N2N	PROD.FISS.	FLUX*VOL.
REGION	1	5.0222E-02	5.7333E-01	5.0139E-02	3.2608E-02	1.3861E-01	1.4758E-03	8.6578E-02	1.7534E 00
	2	2.8797E-02	0.0	0.0	1.1516E-04	5.1840E-02	0.0	0.0	8.6754E-01
	3	9.3040E-03	0.0	9.0109E-04	2.6774E-03	4.0043E-01	2.0147E-03	0.0	4.5330E 00

GROUP 2

		FLUX	SOURCE IJ	SOURCE II	ABSORPTION	SCATT.OUT	PROD. N2N	PROD.FISS.	FLUX*VOL.
REGION	1	7.1006E-02	5.7994E-01	1.3218E-03	1.4202E-02	3.6250E-02	0.0	3.2136E-03	2.4790E 00
	2	4.7613E-02	4.8414E-02	0.0	3.0579E-05	1.7027E-01	0.0	0.0	1.4344E 00
	3	2.1371E-02	4.0215E-01	0.0	2.5092E-05	8.1105E-01	0.0	0.0	1.0412E 01

II) GROUP-AVERAGED REACTIONS RATES

GROUP	FLUX	SOURCE IJ	SOURCE II	ABSORPTION	SCATT.OUT	PROD. N2N	PROD.FISS.
1	1.2954E-02	5.7517E-01	5.1040E-02	3.5400E-02	5.9087E-01	3.4905E-03	8.6578E-02
2	2.5940E-02	1.0305E 00	1.3218E-03	1.4258E-02	1.0176E 00	0.0	3.2136E-03

III) NEUTRON BALANCE FOR FAST RANGE

PRODUCTION = 9.3282E-02

ABSORPTION = 4.9658E-02

IV) ABSORPTION IN FERTILE AND FISSILE MATERIALS

GROUP	FERT.ABS.	FISS.ABS.
1	1.8695E-03	5.3940E-04
2	1.2762E-02	9.2954E-04

B) FAST AND EPITHERMAL RANGE (PETARD)

I) DETAILED REACTION RATES

GROUP 1

		FLUX	SOURCE IJ	SOURCE II	ABSORPTION	SCATT.OUT	PROD. N2N	PROD.FISS.	FLUX*VOL.
REGION	1	6.1400E-02	7.3663E-02	8.7569E-03	5.6950E-03	2.4208E-02	2.5774E-04	1.5121E-02	3.0624E-01
	2	5.6392E-02	0.0	0.0	2.2705E-05	1.2053E-03	0.0	0.0	5.3685E-02
	3	5.5369E-02	0.0	0.0	4.4500E-06	6.2205E-03	0.0	0.0	8.8423E-02
	4	4.9345E-02	4.9998E-01	4.2226E-02	2.7604E-02	1.5632E-01	1.2428E-03	7.2913E-02	2.2314E 00
	5	3.1101E-02	0.0	0.0	1.9225E-05	2.6874E-02	0.0	0.0	3.8201E-01
	6	2.6123E-02	0.0	0.0	7.3822E-05	3.9188E-03	0.0	0.0	1.5265E-01
	7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8	2.2395E-02	0.0	0.0	5.2314E-05	2.7771E-03	0.0	0.0	1.0817E-01
	9	1.7040E-02	0.0	1.7398E-04	5.0767E-04	7.6821E-02	3.8899E-04	0.0	8.3946E-01
	10	1.0494E-02	0.0	2.3444E-04	6.8411E-04	1.0352E-01	5.2418E-04	0.0	1.1312E 00
	11	7.1449E-03	0.0	2.0634E-04	6.0211E-04	9.1111E-02	4.6135E-04	0.0	9.9562E-01
	12	6.3162E-03	0.0	2.2371E-04	6.5278E-04	9.8778E-02	5.0018E-04	0.0	1.0794E 00

GROUP 2

		FLUX	SOURCE IJ	SOURCE II	ABSORPTION	SCATT.OUT	PROD. N2N	PROD.FISS.	FLUX*VOL.
REGION	1	9.8277E-02	8.2298E-02	2.6134E-04	2.8081E-03	7.1675E-03	0.0	6.3541E-04	4.9016E-01
	2	8.9930E-02	1.1558E-03	0.0	8.2359E-06	7.2911E-04	0.0	0.0	8.5612E-02
	3	8.6891E-02	5.7954E-03	0.0	6.9724E-09	2.0816E-02	0.0	0.0	1.3876E-01
	4	7.6493E-02	5.3776E-01	1.2205E-03	1.3156E-02	1.4714E-01	0.0	2.9674E-03	3.4590E 00
	5	5.1933E-02	2.5037E-02	0.0	3.2051E-08	9.5688E-02	0.0	0.0	6.3788E-01
	6	4.6153E-02	3.7580E-03	0.0	2.9667E-05	2.6264E-03	0.0	0.0	2.6969E-01
	7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8	4.2526E-02	2.6631E-03	0.0	2.2596E-05	2.0004E-03	0.0	0.0	2.0541E-01
	9	3.4960E-02	7.7174E-02	0.0	0.0	1.3949E-01	0.0	0.0	1.7222E 00
	10	2.3748E-02	1.0399E-01	0.0	0.0	2.0734E-01	0.0	0.0	2.5600E 00
	11	1.6982E-02	9.1530E-02	0.0	0.0	1.9166E-01	0.0	0.0	2.3664E 00
	12	1.4537E-02	9.9232E-02	0.0	0.0	2.0121E-01	0.0	0.0	2.4844E 00

GROUP 3

		FLUX	SOURCE IJ	SOURCE II	ABSORPTION	SCATT.OUT	PROD. N2N	PROD.FISS.	FLUX*VOL.
REGION	1	2.3804E-02	1.0245E-02	0.0	1.2674E-03	2.8052E-03	0.0	0.0	1.1872E-01
	2	2.3303E-02	7.4958E-04	0.0	7.0950E-06	9.2809E-04	0.0	0.0	2.2184E-02
	3	2.3119E-02	1.5729E-02	0.0	4.3902E-09	1.3238E-02	0.0	0.0	3.6921E-02
	4	2.0980E-02	1.3913E-01	0.0	6.7406E-03	9.1931E-02	0.0	0.0	9.4872E-01
	5	1.7781E-02	7.2222E-02	0.0	2.5970E-08	7.8313E-02	0.0	0.0	2.1841E-01
	6	1.6838E-02	2.6875E-03	0.0	3.5983E-05	4.7069E-03	0.0	0.0	9.8391E-02
	7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8	1.6438E-02	2.0407E-03	0.0	2.9038E-05	3.7984E-03	0.0	0.0	7.9400E-02
	9	1.5807E-02	1.2576E-01	0.0	0.0	1.0114E-01	0.0	0.0	7.7872E-01

10	1.3260E-02	1.8693E-01	0.0	0.0	1.8566E-01	0.0	0.0	1.4294E 00
11	1.0962E-02	1.7279E-01	0.0	0.0	1.9840E-01	0.0	0.0	1.5275E 00
12	9.9432E-03	1.8141E-01	0.0	0.0	2.2070E-01	0.0	0.0	1.6992E 00

GROUP 4

	FLUX	SOURCE IJ	SOURCE II	ABSORPTION	SCATT.OUT	PROD. N2N	PROD.FISS.	FLUX*VOL.
REGION 1	3.8037E-02	2.9170E-03	0.0	3.5672E-03	1.5411E-03	0.0	0.0	1.8971E-01
2	3.8957E-02	9.5665E-04	0.0	4.0832E-06	5.6737E-05	0.0	0.0	3.7086E-02
3	3.9003E-02	1.8215E-02	0.0	1.9034E-06	1.3588E-02	0.0	0.0	6.2287E-02
4	3.7890E-02	1.1885E-01	0.0	2.1356E-02	8.8742E-02	0.0	0.0	1.7134E 00
5	3.7278E-02	1.0067E-01	0.0	1.3992E-05	9.9886E-02	0.0	0.0	4.5788E-01
6	3.7417E-02	4.8051E-03	0.0	2.7526E-05	3.8249E-04	0.0	0.0	2.1864E-01
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	3.7506E-02	3.8709E-03	0.0	2.2808E-05	3.1693E-04	0.0	0.0	1.8116E-01
9	3.6747E-02	1.1486E-01	0.0	2.5324E-07	9.2891E-02	0.0	0.0	1.8103E 00
10	3.4882E-02	2.0603E-01	0.0	5.2602E-07	1.9295E-01	0.0	0.0	3.7602E 00
11	3.2834E-02	2.1722E-01	0.0	6.4003E-07	2.3477E-01	0.0	0.0	4.5752E 00
12	3.1783E-02	2.4046E-01	0.0	7.5982E-07	2.7871E-01	0.0	0.0	5.4315E 00

GROUP 5

	FLUX	SOURCE IJ	SOURCE II	ABSORPTION	SCATT.OUT	PROD. N2N	PROD.FISS.	FLUX*VOL.
REGION 1	1.8434E-02	1.5434E-03	0.0	2.3037E-03	1.2388E-03	0.0	0.0	9.1939E-02
2	1.8830E-02	5.7158E-05	0.0	0.0	4.8487E-05	0.0	0.0	1.7926E-02
3	1.8937E-02	1.2297E-02	0.0	3.4042E-06	1.0697E-02	0.0	0.0	3.0243E-02
4	1.8945E-02	8.1033E-02	0.0	1.4226E-02	7.2136E-02	0.0	0.0	8.5667E-01
5	1.9427E-02	8.9542E-02	0.0	2.6860E-05	8.4398E-02	0.0	0.0	2.3862E-01
6	1.9456E-02	3.8396E-04	0.0	0.0	3.5165E-04	0.0	0.0	1.1369E-01
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	1.9488E-02	3.1802E-04	0.0	0.0	2.9115E-04	0.0	0.0	9.4132E-02
9	1.9448E-02	9.2394E-02	0.0	4.9375E-07	8.6435E-02	0.0	0.0	9.5809E-01
10	1.9180E-02	1.9191E-01	0.0	1.0655E-06	1.8652E-01	0.0	0.0	2.0675E 00
11	1.8765E-02	2.3349E-01	0.0	1.3475E-06	2.3590E-01	0.0	0.0	2.6148E 00
12	1.8522E-02	2.7718E-01	0.0	1.6312E-06	2.8556E-01	0.0	0.0	3.1653E 00

GROUP 6

	FLUX	SOURCE IJ	SOURCE II	ABSORPTION	SCATT.OUT	PROD. N2N	PROD.FISS.	FLUX*VOL.
REGION 1	8.3617E-03	1.2390E-03	0.0	1.5745E-03	1.1207E-03	0.0	0.0	4.1705E-02
2	8.6040E-03	4.8501E-05	0.0	1.0788E-06	4.4363E-05	0.0	0.0	8.1909E-03
3	8.6783E-03	8.1142E-03	0.0	3.2559E-06	7.3469E-03	0.0	0.0	1.3859E-02
4	8.8025E-03	5.6417E-02	0.0	9.9712E-03	5.2063E-02	0.0	0.0	3.9804E-01
5	9.2692E-03	6.3316E-02	0.0	2.6747E-05	6.0354E-02	0.0	0.0	1.1385E-01
6	9.3399E-03	3.5170E-04	0.0	8.2193E-06	3.3801E-04	0.0	0.0	5.4577E-02
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	9.3689E-03	2.9119E-04	0.0	6.8152E-06	2.8027E-04	0.0	0.0	4.5254E-02
9	9.4154E-03	7.1342E-02	0.0	4.9901E-07	6.9111E-02	0.0	0.0	4.6383E-01
10	9.4284E-03	1.5392E-01	0.0	1.0934E-06	1.5144E-01	0.0	0.0	1.0164E 00
11	9.3633E-03	1.9461E-01	0.0	1.4037E-06	1.9440E-01	0.0	0.0	1.3047E 00
12	9.3116E-03	2.3556E-01	0.0	1.7120E-06	2.3710E-01	0.0	0.0	1.5913E 00

GROUP 7

	FLUX	SOURCE IJ	SOURCE II	ABSORPTION	SCATT.OUT	PROD. N2N	PROD.FISS.	FLUX*VOL.

REGION	1	3.4374E-03	1.1207E-03	0.0	1.6207E-03	9.4411E-04	0.0	1.8675E-04	1.7145E-02
	2	3.6843E-03	4.4365E-05	0.0	1.8493E-06	3.8017E-05	0.0	0.0	3.5074E-03
	3	3.7576E-03	4.9254E-03	0.0	1.9979E-06	4.1377E-03	0.0	0.0	6.0009E-03
	4	3.8841E-03	3.7130E-02	0.0	1.1012E-02	3.2303E-02	0.0	1.2661E-03	1.7563E-01
	5	4.3845E-03	3.9736E-02	0.0	1.7929E-05	3.7133E-02	0.0	0.0	5.3853E-02
	6	4.4715E-03	3.3802E-04	0.0	1.5754E-05	3.2385E-04	0.0	0.0	2.6129E-02
	7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8	4.5036E-03	2.8028E-04	0.0	1.3116E-05	2.6962E-04	0.0	0.0	2.1753E-02
	9	4.5729E-03	4.7536E-02	0.0	3.4337E-07	4.5859E-02	0.0	0.0	2.2528E-01
	10	4.6451E-03	1.0379E-01	0.0	7.6322E-07	1.0193E-01	0.0	0.0	5.0073E-01
	11	4.6555E-03	1.3278E-01	0.0	9.8878E-07	1.3206E-01	0.0	0.0	6.4872E-01
	12	4.6471E-03	1.6167E-01	0.0	1.2105E-06	1.6167E-01	0.0	0.0	7.9417E-01

GROUP 8

		FLUX	SOURCE IJ	SOURCE II	ABSORPTION	SCATT.OUT	PROD. N2N	PROD.FISS.	FLUX*VOL.
REGION	1	6.9303E-03	9.4411E-04	0.0	2.2648E-03	9.1893E-04	0.0	5.9852E-04	3.4565E-02
	2	7.2612E-03	3.8019E-05	0.0	3.6447E-06	3.7446E-05	0.0	0.0	6.9126E-03
	3	7.3721E-03	7.0906E-03	0.0	5.7634E-06	6.2775E-03	0.0	0.0	1.1773E-02
	4	7.6867E-03	4.9925E-02	0.0	1.5131E-02	4.5626E-02	0.0	3.9831E-03	3.4759E-01
	5	8.5557E-03	5.9648E-02	0.0	5.1445E-05	5.6034E-02	0.0	0.0	1.0509E-01
	6	8.7361E-03	3.2386E-04	0.0	3.0778E-05	3.1622E-04	0.0	0.0	5.1048E-02
	7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8	8.8038E-03	2.6963E-04	0.0	2.5639E-05	2.6342E-04	0.0	0.0	4.2524E-02
	9	8.9595E-03	6.8212E-02	0.0	9.8926E-07	6.5775E-02	0.0	0.0	4.4138E-01
	10	9.1602E-03	1.5044E-01	0.0	2.2132E-06	1.4715E-01	0.0	0.0	9.8745E-01
	11	9.2416E-03	1.9386E-01	0.0	2.8863E-06	1.9191E-01	0.0	0.0	1.2878E 00
	12	9.2554E-03	2.3680E-01	0.0	3.5451E-06	2.3571E-01	0.0	0.0	1.5817E 00

GROUP 9

		FLUX	SOURCE IJ	SOURCE II	ABSORPTION	SCATT.OUT	PROD. N2N	PROD.FISS.	FLUX*VOL.
REGION	1	9.3385E-03	9.1893E-04	0.0	3.5810E-03	8.2277E-04	0.0	5.9035E-04	4.6577E-02
	2	9.8192E-03	3.7447E-05	0.0	8.2118E-06	3.4426E-05	0.0	0.0	9.3477E-03
	3	9.9888E-03	7.9826E-03	0.0	1.4885E-05	6.9985E-03	0.0	0.0	1.5952E-02
	4	1.0580E-02	5.5817E-02	0.0	2.4490E-02	5.0291E-02	0.0	4.0129E-03	4.7841E-01
	5	1.2073E-02	6.9597E-02	0.0	1.3836E-04	6.5057E-02	0.0	0.0	1.4829E-01
	6	1.2436E-02	3.1622E-04	0.0	7.3000E-05	3.0604E-04	0.0	0.0	7.2670E-02
	7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8	1.2575E-02	2.6342E-04	0.0	6.1015E-05	2.5579E-04	0.0	0.0	6.0740E-02
	9	1.2899E-02	7.6406E-02	0.0	2.7150E-06	7.2905E-02	0.0	0.0	6.3547E-01
	10	1.3362E-02	1.7058E-01	0.0	6.1539E-06	1.6525E-01	0.0	0.0	1.4403E 00
	11	1.3615E-02	2.2206E-01	0.0	8.1058E-06	2.1766E-01	0.0	0.0	1.8972E 00
	12	1.3696E-02	2.7252E-01	0.0	1.0000E-05	2.6853E-01	0.0	0.0	2.3406E 00

II) GROUP-AVERAGED REACTIONS RATES

GROUP	FLUX	SOURCE IJ	SOURCE II	ABSORPTION	SCATT.OUT	PROD. N2N	PROD.FISS.
1	1.3342E-02	5.7571E-01	5.1821E-02	3.5918E-02	5.9176E-01	3.3753E-03	8.8034E-02
2	2.6110E-02	1.0304E 00	1.4818E-03	1.6025E-02	1.0159E 00	0.0	3.6028E-03
3	1.2599E-02	9.0970E-01	0.0	8.0801E-03	9.0162E-01	0.0	0.0

4	3.3386E-02	1.0288E 00	0.0	2.4996E-02	1.0038E 00	0.0	0.0
5	1.8558E-02	9.8015E-01	0.0	1.6565E-02	9.6357E-01	0.0	0.0
6	9.1475E-03	7.8520E-01	0.0	1.1597E-02	7.7360E-01	0.0	0.0
7	4.4779E-03	5.2935E-01	0.0	1.2686E-02	5.1667E-01	0.0	1.4528E-03
8	8.8688E-03	7.6755E-01	0.0	1.7523E-02	7.5002E-01	0.0	4.5816E-03
9	1.2939E-02	8.7650E-01	0.0	2.8393E-02	8.4810E-01	0.0	4.6033E-03

III) NEUTRON BALANCE FOR *FAST* AND *EPITHERMAL* RANGE

PRODUCTION =	9.5012E-02	1.0638E-02
ABSORPTION =	5.1943E-02	1.1984E-01

IV) ABSORPTION IN FERTILE AND FISSILE MATERIALS

GROUP	FERT.ABS.	FISS.ABS.
1	1.9009E-03	5.4847E-04
2	1.4308E-02	1.0421E-03
3	7.9695E-03	0.0
4	2.4888E-02	0.0
5	1.6509E-02	0.0
6	1.1519E-02	0.0
7	1.1375E-02	1.2333E-03
8	1.3005E-02	4.3307E-03
9	2.4265E-02	3.6543E-03

C) THERMAL RANGE (THEMIS)

I) DETAILED REACTION RATES

GROUP 1

		FLUX	SOURCE IJ	SOURCE II	ABSORPTION	SCATT.OUT	PROD. N2N	PROD.FISS.	FLUX*VOL.
REGION	1	1.0935E-01	8.2277E-04	0.0	7.9962E-02	0.0	0.0	1.0368E-01	5.4537E-01
	2	1.1797E-01	3.4426E-05	0.0	8.8644E-04	0.0	0.0	0.0	1.1231E-01
	3	1.2502E-01	9.1706E-03	0.0	1.6096E-03	0.0	0.0	0.0	1.9966E-01
	4	1.5124E-01	6.3743E-02	0.0	7.6713E-01	0.0	0.0	9.7330E-01	6.8389E 00
	5	2.2926E-01	8.3969E-02	0.0	2.8818E-02	0.0	0.0	0.0	2.8159E 00
	6	2.6486E-01	3.0604E-04	0.0	1.7733E-02	0.0	0.0	0.0	1.5477E 00
	7	2.6828E-01	0.0	0.0	0.0	0.0	0.0	0.0	2.4779E 00
	8	2.7170E-01	2.5579E-04	0.0	1.5037E-02	0.0	0.0	0.0	1.3124E 00
	9	2.9400E-01	7.7133E-02	0.0	1.1265E-03	0.0	0.0	0.0	1.4483E 01
	10	3.5264E-01	6.8834E-01	0.0	1.1466E-02	0.0	0.0	0.0	1.4742E 02

II) GROUP-AVERAGED REACTIONS RATES

GROUP	FLUX	SOURCE IJ	SOURCE II	ABSORPTION	SCATT.OUT	PROD. N2N	PROD.FISS.
1	3.2187E-01	9.2377E-01	0.0	9.2377E-01	0.0	0.0	1.0770E 00

III) NEUTRON BALANCE FOR THERMAL RANGE

PRODUCTION = 1.0770E 00

ABSORPTION = 9.2377E-01

IV) ABSORPTION IN FERTILE AND FISSILE MATERIALS

GROUP	FERT.ABS.	FISS.ABS.
1	3.0308E-01	5.2067E-01

7) FEW-GROUP PARAMETERS (CELL-AVERAGED)

BROAD GROUP	FINE GROUPS	PRODUCTION	ABSORPTION	DIFF.COEFF.	SCATT.OUT	MEAN FLUX
1	1-2-	4.3428E-03	2.3119E-03	1.5265E 00	4.7871E-02	3.8894E-02
2	3-4-	0.0	1.3024E-03	1.1758E 00	3.9719E-02	4.5985E-02
3	5-6-7-8-9-	3.5677E-04	2.9099E-03	1.1815E 00	3.0964E-02	5.3992E-02
4	10-	6.0589E-03	5.1970E-03	8.6764E-01	0.0	3.2187E-01

TRANSFER KERNEL BETWEEN BROAD GROUPS

FROM / TO	1	2	3	4
1	2.0049E-01			
2	4.7784E-02	2.5163E-01		
3	8.6764E-05	3.9699E-02	2.5410E-01	
4	2.1474E-07	1.9877E-05	3.0964E-02	4.6850E-01

8) FEW-GROUP PARAMETERS (MOD.-AVERAGED)

BROAD GROUP	FINE GROUPS	PRODUCTION	ABSORPTION	DIFF.COEFF.	SCATT.OUT	MEAN FLUX
1	1-2-	1.4225E-04	1.8565E-04	1.5298E 00	5.4287E-02	2.8202E-02
2	3-4-	0.0	1.0371E-07	1.2557E 00	3.8053E-02	4.4965E-02
3	5-6-7-8-9-	0.0	1.8935E-06	1.2384E 00	2.9482E-02	5.5559E-02
4	10-	0.0	7.7779E-05	8.7889E-01	0.0	3.4646E-01

TRANSFER KERNEL BETWEEN BROAD GROUPS

FROM / TO	1	2	3	4
1	1.8885E-01			
2	5.4283E-02	2.2740E-01		
3	3.7041E-06	3.8052E-02	2.3969E-01	
4	9.1909E-09	1.8053E-06	2.9482E-02	4.4898E-01

9) FEW-GROUP PARAMETERS (FUEL-AVERAGED)

BROAD GROUP	FINE GROUPS	PRODUCTION	ABSORPTION	DIFF.COEFF.	SCATT.OUT	MEAN FLUX
1	1-2-	1.1012E-02	5.6875E-03	1.5213E 00	3.3197E-02	1.0134E-01
2	3-4-	0.0	7.5461E-03	7.9270E-01	4.7706E-02	5.1594E-02
3	5-6-7-8-9-	2.7600E-03	2.2499E-02	7.9880E-01	4.0950E-02	4.5371E-02
4	10-	6.7948E-02	5.7487E-02	7.5278E-01	0.0	1.8658E-01

TRANSFER KERNEL BETWEEN BROAD GROUPS

FROM / TO	1	2	3	4
1	2.1831E-01			
2	3.2988E-02	3.6781E-01		
3	2.0872E-04	4.7600E-02	3.5120E-01	
4	5.1653E-07	1.0652E-04	4.0950E-02	6.6793E-01

10) OVER-ALL NEUTRON BALANCE

CONVERSION RATIO	=	8.0406E-01
TOTAL PRODUCTION	=	1.1809E 00
TOTAL ABSORPTION	=	1.0933E 00
INFINITE MULTIPLICATION FACTOR (PRODUCTION/ABSORPTION)	=	1.0802E 00
INFINITE MULTIPLICATION FACTOR (4-FACTOR FORMULA)	=	1.0876E 00
MATERIAL BUCKLING - INIT. GUESS	=	3.4759E-04
MATERIAL BUCKLING - EIGENVALUE	=	3.2784E-04
EXPERIMENTAL BUCKLING	=	3.3700E-04
EFFECTIVE MULTIPLICATION FACTOR	=	9.9788E-01

11) THREE-GROUP PARAMETERS (FOR HETEROGENEOUS PARAMETERS CALCULATION) CELL-AVERAGED

BROAD GROUP	FINE GROUPS	PRODUCTION	ABSORPTION	DIFF.COEFF.	SCATT.OUT	MEAN FLUX
1	1-2-3-4-	1.9900E-03	1.7650E-03	1.3365E 00	2.1558E-02	8.4879E-02
2	5-6-7-8-9-	3.5677E-04	2.9099E-03	1.1815E 00	3.0964E-02	5.3992E-02
3	10-	6.0589E-03	5.1970E-03	8.6764E-01	0.0	3.2187E-01

TRANSFER KERNEL BETWEEN BROAD GROUPS

TO \ FROM	1	2	3
1	2.5009E-01		
2	2.1548E-02	2.5410E-01	
3	1.0867E-05	3.0964E-02	4.6850E-01

MOD.-AVERAGED

BROAD GROUP	FINE GROUPS	PRODUCTION	ABSORPTION	DIFF.COEFF.	SCATT.OUT	MEAN FLUX
1	1-2-3-4-	5.4831E-05	7.1623E-05	1.3614E 00	2.3387E-02	7.3166E-02
2	5-6-7-8-9-	0.0	1.8935E-06	1.2384E 00	2.9482E-02	5.5559E-02
3	10-	0.0	7.7779E-05	8.7889E-01	0.0	3.4646E-01

TRANSFER KERNEL BETWEEN BROAD GROUPS

TO \ FROM	1	2	3
1	2.3346E-01		
2	2.3386E-02	2.3969E-01	
3	1.1130E-06	2.9482E-02	4.4898E-01

FUEL-AVERAGED

BROAD GROUP	FINE GROUPS	PRODUCTION	ABSORPTION	DIFF.COEFF.	SCATT.OUT	MEAN FLUX
1	1-2-3-4-	7.2969E-03	6.3145E-03	1.2755E 00	1.6233E-02	1.5294E-01
2	5-6-7-8-9-	2.7600E-03	2.2499E-02	7.9880E-01	4.0950E-02	4.5371E-02
3	10-	6.7948E-02	5.7487E-02	7.5278E-01	0.0	1.8658E-01

TRANSFER KERNEL BETWEEN BROAD GROUPS

TO \ FROM	1	2	3
1	2.9061E-01		
2	1.6196E-02	3.5120E-01	
3	3.6276E-05	4.0950E-02	6.6793E-01

12) THREE-GROUP HETEROGENEOUS PARAMETERS

	GAMMA			SURF. FLUX	DIP. TERMS
FROM / TO	1	2	3		
1	3.7532E-02	-4.2290E-03	-8.5490E-02	1.1868E-01	1.7057E-01
2	-4.3820E-02	1.0688E-01	0.0	5.6552E-02	1.4138E-01
3	-1.3829E-04	-9.7191E-02	1.1204E-01	2.8322E-01	1.7686E-01

ISPRA 6/2/68 BURN-UP SINGLE ROD PITCH 15.6849

1) GENERAL DESCRIPTION

GEOMETRY

NUMBER OF FUEL RODS	=	1
TYPE OF LATTICE	=	SQUARE
GEOMETRICAL CONFIGURATION NUMBER	=	2
NUMBER OF ISOTOPS	=	8
RADIUS FUEL ROD	=	1.727200
RADIUS CANNING	=	1.927999
DISTANCE BETWEEN RODS	=	0.0
PITCH	=	15.684899
RADIUS INT. OF PRESS. TUBE	=	2.076799
RADIUS EXT. OF PRESS. TUBE	=	2.209800
RADIUS INT. OF CAL. TUBE	=	2.209800
RADIUS EXT. OF CAL. TUBE	=	2.209800

ATOMIC DENSITIES, TEMPERATURES, DENSITY FUEL, PURITY D2O AND VOLUMES OF PURE MATERIALS

	FUEL 1	FUEL 2	FUEL 3	CANNING	COOLANT	FILLER	PR. TUBE	INS. LAYER	CAL. TUBE	MODERATOR
TEM.(C)	600	600	600	27	150	27	27	27	27	60
DENSITY	1.0422E 01									
235	3.4351E-04	3.4351E-04	3.4351E-04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
238	4.7354E-02	4.7354E-02	4.7354E-02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
239	1.0000E-12	1.0000E-12	1.0000E-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
240	1.0000E-12	1.0000E-12	1.0000E-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	6.0200E-02	0.0	0.0	6.0200E-02	0.0	0.0	0.0
12001	0.0	0.0	0.0	0.0	6.7000E-02	0.0	0.0	0.0	0.0	0.0
10016	0.0	0.0	0.0	0.0	3.3500E-02	0.0	0.0	0.0	0.0	3.3100E-02
12002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.6200E-02
PART.V.	3.7488E-01	2.9991E 00	5.9981E 00	2.3058E 00	1.8721E 00	0.0	1.7911E 00	0.0	0.0	2.3067E 02
TOT.V.	3.7488E-01	2.9991E 00	5.9981E 00	2.3058E 00	1.8721E 00	0.0	1.7911E 00	0.0	0.0	2.3067E 02

ISOTOPES WITH RESONANCE ABSORPTION 235 238

FOR BURN-UP CALCULATION (DETAILED)

POWER = 4.1000E 13
DELTA TIME = 3.0000E 06

TIME STEPS

COMPLETE CELL CALCULATION = 1
THERMAL CALC. ONLY (SPECTRAL AND SPATIAL) = 1
THERMAL CALC. ONLY (SPATIAL) = 1
DEPLETION CHAINS = 4

CHAINS

DEPLETION

2
3

FISSION PRODUCTS

13
14
15
16
17
18
19
20
21
22
23
24

TIME = 0.0

5) CRITICALITY

THERMAL UTILISATION FACTOR	9.4954032E-01
THERMAL FISSION FACTOR	1.3037519E 00
THERMAL MULTIPLICATION FACTOR	1.2379656E 00
RESONANCE ESCAPE PROBABILITY	8.9345700E-01
FAST FISSION FACTOR	1.0427523E 00
INFINITE MULTIPLICATION FACTOR (4-FACTOR FORMULA)	1.1625051E 00
THERMAL DIFFUSION AREA	1.8355295E 02

10) OVER-ALL NEUTRON BALANCE

CONVERSION RATIO	=	7.8625E-01
TOTAL PRODUCTION	=	1.2576E 00
TOTAL ABSORPTION	=	1.0951E 00
INFINITE MULTIPLICATION FACTOR (PRODUCTION/ABSORPTION)	=	1.1484E 00
INFINITE MULTIPLICATION FACTOR (4-FACTOR FORMULA)	=	1.1625E 00
MATERIAL BUCKLING - INIT. GUESS	=	5.8984E-04
MATERIAL BUCKLING - EIGENVALUE	=	5.4526E-04
EXPERIMENTAL BUCKLING	=	0.0
EFFECTIVE MULTIPLICATION FACTOR	=	1.1489E 00

13) BURN-UP

A) LINEAR CHAIN MACROSCOPIC ABSORPTION CROSS SECTIONS

REGION	1	2	3
CHAIN 13	1.1966E-05	1.2069E-05	1.8125E-05
CHAIN 14	1.7909E-05	1.9998E-05	2.6444E-05
CHAIN 15	2.1828E-05	2.4025E-05	2.5148E-05
CHAIN 16	7.4875E-06	8.2992E-06	1.2298E-05
CHAIN 17	1.4220E-05	1.5636E-05	2.2800E-05
CHAIN 18	3.0010E-05	3.3327E-05	5.0899E-05
CHAIN 19	2.2115E-03	2.3450E-03	2.5542E-03
CHAIN 20	6.2895E-04	6.6318E-04	7.0775E-04
CHAIN 21	7.4392E-05	8.2012E-05	1.2327E-04
CHAIN 22	2.3942E-05	2.6255E-05	2.7741E-05
CHAIN 23	5.3647E-06	5.5626E-06	6.2801E-06
CHAIN 24	1.6476E-05	1.9061E-05	2.5026E-05

B) FISSION PRODUCT TOTAL MACROSCOPIC ABSORPTION CROSS SECTIONS

REGION	1	2	3
	3.0365E-03	2.2228E-03	4.0682E-03

C) FISSION PRODUCT TOTAL MACR. ABS. CROSS SECT. IN THE CELL = 3.7565E-03

D) FISSIONS IN THE CELL FOR THE TIME-STEP

ISOTOPS	FISSIONS
233	0.0
235	1.1298E 20
238	7.5580E 18
239	2.7663E 18
241	4.1368E 14
242	0.0

E) TOTAL FISSIONS IN THE CELL = 1.2331E 20

14) ATOMIC DENSITIES FOR THE NEXT TIME-STEP (ATOM PER CM**3)

CHAIN 2 (DEPLETION)

REGION	1	2	3
ISOTOP 2	3.3183E 20	3.3111E 20	3.2800E 20
ISOTOP 11	1.8991E 18	2.0095E 18	2.4838E 18

CHAIN 3 (DEPLETION)

REGION	1	2	3
ISOTOP 3	4.7344E 22	4.7343E 22	4.7341E 22
ISOTOP 12	6.5404E 15	6.8341E 15	8.0972E 15
ISOTOP 13	9.5519E 17	9.9806E 17	1.1824E 18
ISOTOP 4	8.5859E 18	8.9566E 18	1.0532E 19
ISOTOP 14	9.2139E 16	1.0025E 17	1.4096E 17
ISOTOP 5	1.6873E 15	1.7463E 15	2.6820E 15

CHAIN 13 (FISSION PRODUCTS)

REGION	1	2	3
ISOTOP 43	7.5659E 16	8.0037E 16	9.7956E 16
ISOTOP 44	5.8573E 17	6.1973E 17	7.5832E 17
ISOTOP 45	0.0	2.3556E 14	2.8502E 14
ISOTOP 46	5.4981E 17	5.8191E 17	7.1143E 17
ISOTOP 47	4.5723E 17	4.8475E 17	5.8944E 17
ISOTOP 48	2.7352E 17	2.8799E 17	3.4443E 17
ISOTOP 49	9.0792E 16	9.5507E 16	1.1422E 17
ISOTOP 50	3.4021E 14	4.0582E 14	5.5078E 14
ISOTOP 16	0.0	1.1542E 15	0.0

CHAIN 14 (FISSION PRODUCTS)

REGION	1	2	3
ISOTOP 15	7.7648E 15	8.1388E 15	9.5355E 15
ISOTOP 16	1.1695E 17	1.2261E 17	1.4374E 17
ISOTOP 52	0.0	0.0	7.9162E 12
ISOTOP 54	4.3279E 16	4.5977E 16	5.1912E 16
ISOTOP 55	2.6330E 16	2.7735E 16	3.2462E 16
ISOTOP 56	9.0624E 15	9.5401E 15	1.1422E 16

CHAIN 15 (FISSION PRODUCTS)

REGION	1	2	3
ISOTOP 57	2.26[illegible]E 16	2.40[illegible]E 16	3.[illegible]E 16
ISOTOP 58	2.[illegible]E 17	2.43[illegible]E 17	3.[illegible]E 17
ISOTOP 59	4.72[illegible]E 17	5.[illegible]E 17	6.[illegible]E 17

CHAIN 16 (FISSION PRODUCTS)

REGION	1	2	3
ISOTOP 60	2.66[illegible]E 16	2.8176E 16	3.4691E 16
ISOTOP 61	1.59[illegible]E 17	1.6884E 17	2.[illegible]E 17
ISOTOP 62	8.70[illegible]E 17	9.18[illegible]E 17	1.[illegible]E 18
ISOTOP 36	6.63[illegible]E 10	6.[illegible]E 10	8.36[illegible]E 10

CHAIN 17 (FISSION PRODUCTS)

REGION	1	2	3
ISOTOP 60	2.6602E 16	2.8176E 16	3.4691E 16
ISOTOP 61	1.5943E 17	1.6884E 17	2.[illegible]E 17
ISOTOP 64	5.5064E 17	5.8317E 17	7.1752E 17
ISOTOP 65	6.2555E 14	6.9242E 14	9.9874E 14

CHAIN 18 (FISSION PRODUCTS)

REGION	1	2	3
ISOTOP 66	3.6713E 16	3.8864E 16	4.7725E 16
ISOTOP 67	2.9858E 17	3.1603E 17	3.8779E 17
ISOTOP 68	3.0991E 17	3.2694E 17	4.[illegible]E 17

CHAIN 19 (FISSION PRODUCTS)

REGION	1	2	3
ISOTOP 31	7.6812E 15	8.1306E 15	9.9806E 15
ISOTOP 36	2.6614E 15	2.7058E 15	2.8292E 15

REGION	1	2	3
ISOTOP 17	4.2669E 17	4.5160E 17	5.5404E 17
ISOTOP 18	3.3254E 17	3.5202E 17	4.3167E 17
ISOTOP 19	1.0564E 17	1.1171E 17	1.3647E 17
ISOTOP 20	1.5046E 17	1.5906E 17	1.9405E 17
ISOTOP 21	1.6429E 15	1.6903E 15	1.8665E 15
ISOTOP 23	1.2168E 16	1.2783E 16	1.5484E 16
ISOTOP 24	2.7231E 16	2.7615E 16	2.8192E 16
ISOTOP 25	3.4964E 17	3.5574E 17	3.7291E 17
ISOTOP 26	3.5155E 15	3.4498E 15	3.2101E 15
ISOTOP 27	1.0826E 17	1.1074E 17	1.1719E 17
ISOTOP 28	1.7195E 15	1.8101E 15	2.1573E 15
ISOTOP 29	7.0585E 16	7.1534E 16	7.3054E 16
ISOTOP 30	1.5883E 16	1.5971E 16	1.5593E 16
ISOTOP 53	1.8122E 15	1.8095E 15	1.7333E 15

CHAIN 21 (FISSION PRODUCTS)

REGION	1	2	3
ISOTOP 32	7.5216E 16	7.9515E 16	9.6959E 16
ISOTOP 33	2.4737E 15	2.6136E 15	3.1799E 15
ISOTOP 26	3.9048E 16	4.0597E 16	4.6269E 16
ISOTOP 27	8.7148E 15	9.8607E 15	1.5088E 16
ISOTOP 28	1.1718E 13	1.3873E 13	2.5356E 13
ISOTOP 29	4.3387E 13	5.1410E 13	9.5311E 13
ISOTOP 30	1.6903E 11	1.6671E 11	6.5446E 11
ISOTOP 53	0.0	0.0	1.9348E 09

CHAIN 22 (FISSION PRODUCTS)

REGION	1	2	3
ISOTOP 17	4.2669E 17	4.5160E 17	5.5404E 17
ISOTOP 18	3.3254E 17	3.5202E 17	4.3167E 17
ISOTOP 19	1.0564E 17	1.1171E 17	1.3647E 17
ISOTOP 20	1.5046E 17	1.5906E 17	1.9405E 17
ISOTOP 22	8.6429E 14	1.0296E 15	1.3081E 15
ISOTOP 23	1.3514E 13	1.5264E 13	2.3954E 13
ISOTOP 24	2.6646E 13	2.8838E 13	3.7955E 13
ISOTOP 25	1.5819E 16	1.6626E 16	1.9514E 16
ISOTOP 26	2.0428E 14	2.0855E 14	2.2637E 14
ISOTOP 27	4.6408E 15	4.9089E 15	5.8859E 15
ISOTOP 28	7.3224E 12	8.0084E 12	1.1561E 13
ISOTOP 29	5.1645E 15	5.4389E 15	6.4822E 15
ISOTOP 30	9.8441E 14	1.0381E 15	1.2282E 15

ISOTOP 53	1.1123E 14	1.1647E 14	1.3528E 14

CHAIN 23 (FISSION PRODUCTS)

REGION	1	2	3
ISOTOP 70	3.3435E 13	3.5041E 13	4.1947E 13
ISOTOP 71	1.3129E 14	1.2807E 14	1.1623E 14

CHAIN 24 (FISSION PRODUCTS)

REGION	1	2	3
ISOTOP 72	1.3006E 19	1.3763E 19	1.6863E 19

FISSION PRODUCT MACROSCOPIC ABSORPTION CROSS SECTIONS

CHAIN 13

REGION	1	2	3
ISOTOP 43	0.0	0.0	0.0
ISOTOP 44	4.90735E-06	5.36205E-06	7.61851E-06
ISOTOP 45	0.0	0.52790E-10	1.40241E-09
ISOTOP 46	1.62945E-06	1.54846E-06	2.12566E-06
ISOTOP 47	2.99515E-07	3.24667E-07	4.61136E-07
ISOTOP 48	0.0	0.0	0.0
ISOTOP 49	5.32461E-06	5.72346E-06	7.81136E-06
ISOTOP 50	3.27652E-09	4.90066E-09	6.76196E-09
ISOTOP 16	0.0	4.76216E-09	0.0

CHAIN 14

REGION	1	2	3
ISOTOP 15	1.68635E-05	1.87716E-05	2.77906E-05
ISOTOP 16	4.67925E-07	5.05946E-07	6.84276E-07
ISOTOP 52	0.0	0.0	1.57566E-11
ISOTOP 54	1.37976E-07	1.48756E-07	1.96886E-07
ISOTOP 55	1.36345E-07	1.45796E-07	1.86876E-07
ISOTOP 56	3.93236E-07	4.26086E-07	5.85916E-07

CHAIN 15

REGION	1	2	3
ISOTOP 57	0.0	0.0	0.0
ISOTOP 58	2.67605E-06	2.90466E-06	4.42636E-06
ISOTOP 59	1.92226E-05	2.11216E-05	3.07226E-05

CHAIN 16

REGION	1	2	3
ISOTOP 60	0.0	0.0	0.0
ISOTOP 61	7.35026E-06	8.15086E-06	1.22216E-05
ISOTOP 62	7.31946E-08	7.99856E-08	1.09476E-07
ISOTOP 26	5.50965E-08	6.02996E-08	8.73056E-08

CHAIN 17

REGION	1	2	3
ISOTOP 60	0.0	0.0	0.0
ISOTOP 61	7.3592E-06	8.1598E-06	1.2291E-05
ISOTOP 64	6.8207E-06	7.4532E-06	1.1567E-05
ISOTOP 65	2.0173E-08	2.2418E-08	4.1286E-08

CHAIN 18

REGION	1	2	3
ISOTOP 66	5.1241E-08	5.6945E-08	8.5702E-08
ISOTOP 67	6.3442E-06	7.0426E-06	1.0571E-05
ISOTOP 68	2.3615E-05	2.6237E-05	3.9433E-05

CHAIN 19

REGION	1	2	3
ISOTOP 31	0.0	0.0	0.0
ISOTOP 36	2.2115E-03	2.3459E-03	2.9543E-03

CHAIN 20

REGION	1	2	3
ISOTOP 17	7.8923E-06	8.6886E-06	1.2683E-05
ISOTOP 18	8.0261E-07	8.8992E-07	1.3283E-06
ISOTOP 19	0.0	0.0	0.0
ISOTOP 20	1.1519E-05	1.2561E-05	1.7725E-05
ISOTOP 21	1.0329E-05	1.1151E-05	1.5078E-05
ISOTOP 23	0.0	0.0	0.0
ISOTOP 24	5.5389E-04	5.7994E-04	6.9389E-04
ISOTOP 25	8.5182E-06	9.0392E-06	1.1310E-05
ISOTOP 26	6.6277E-06	6.9689E-06	8.3739E-06
ISOTOP 27	8.9842E-06	9.5071E-06	1.1757E-05
ISOTOP 28	0.0	0.0	0.0
ISOTOP 29	8.3806E-06	8.8559E-06	1.0848E-05
ISOTOP 30	6.1019E-06	6.3916E-06	7.5032E-06
ISOTOP 53	5.9071E-06	6.1891E-06	7.2594E-06

CHAIN 21

REGION	1	2	3
ISOTOP 32	4.5641E-08	4.9428E-08	6.7702E-08
ISOTOP 33	0.0	0.0	0.0
ISOTOP 26	7.3618E-05	8.2010E-05	1.2067E-04
ISOTOP 27	7.2321E-07	8.4658E-07	1.5138E-06
ISOTOP 28	0.0	0.0	0.0
ISOTOP 29	5.1514E-09	6.3645E-09	1.4153E-08
ISOTOP 30	6.4957E-11	6.6718E-11	3.1491E-10
ISOTOP 53	0.0	0.0	4.3341E-12

CHAIN 22

REGION	1	2	3
ISOTOP 17	7.8923E-06	8.6886E-06	1.2683E-05
ISOTOP 18	8.0261E-07	8.8992E-07	1.3283E-06
ISOTOP 19	0.0	0.0	0.0
ISOTOP 20	1.1519E-05	1.2561E-05	1.7725E-05
ISOTOP 22	6.7619E-07	7.5741E-07	1.1776E-06
ISOTOP 23	0.0	0.0	0.0
ISOTOP 24	5.4220E-07	6.0563E-07	9.3420E-07
ISOTOP 25	3.8607E-07	4.2247E-07	5.9186E-07
ISOTOP 26	3.8514E-07	4.2148E-07	5.9051E-07
ISOTOP 27	3.8512E-07	4.2146E-07	5.9044E-07
ISOTOP 28	0.0	0.0	0.0
ISOTOP 29	6.1319E-07	6.7334E-07	9.6253E-07
ISOTOP 30	3.7820E-07	4.1544E-07	5.9099E-07
ISOTOP 53	3.6255E-07	3.9838E-07	5.6656E-07

CHAIN 23

REGION	1	2	3
ISOTOP 70	0.0	0.0	0.0
ISOTOP 71	5.3647E-06	5.5636E-06	6.3801E-06

CHAIN 24

REGION	1	2	3
ISOTOP 72	1.6476E-05	1.8061E-05	2.5906E-05

FOR BURN-UP CALCULATION (DETAILED)

POWER = 2.0500E 13
DELTA TIME = 6.0000E 06

TIME STEPS

COMPLETE CELL CALCULATION	= 1
THERMAL CALC. ONLY (SPECTRAL AND SPATIAL)	= 1
THERMAL CALC. ONLY (SPATIAL)	= 1
DEPLETION CHAINS	= 8

1) ATOMIC DENSITIES (FUEL) AT THE TIME 3.0000E 06

	FUEL 1	FUEL 2	FUEL 3
235	3.3183E-04	3.3111E-04	3.2800E-04
238	4.7343E-02	4.7343E-02	4.7341E-02
239	8.5859E-06	8.9566E-06	1.0532E-05
240	9.2139E-08	1.0025E-07	1.4096E-07
27	0.0	0.0	0.0
12001	0.0	0.0	0.0
10016	0.0	0.0	0.0
12002	0.0	0.0	0.0

5) CRITICALITY

THERMAL UTILISATION FACTOR	9.5120746E-01
THERMAL FISSION FACTOR	1.2611361E 00
THERMAL MULTIPLICATION FACTOR	1.1996021E 00
RESONANCE ESCAPE PROBABILITY	8.9343423E-01
FAST FISSION FACTOR	1.0402079E 00
INFINITE MULTIPLICATION FACTOR (4-FACTOR FORMULA)	1.1236353E 00
THERMAL DIFFUSION AREA	1.7966205E 02

10) OVER-ALL NEUTRON BALANCE

CONVERSION RATIO	=	7.8224E-01
TOTAL PRODUCTION	=	1.2186E 00
TOTAL ABSORPTION	=	1.0950E 00
INFINITE MULTIPLICATION FACTOR (PRODUCTION/ABSORPTION)	=	1.1129E 00
INFINITE MULTIPLICATION FACTOR (4-FACTOR FORMULA)	=	1.1237E 00
MATERIAL BUCKLING - INIT. GUESS	=	4.5579E-04
MATERIAL BUCKLING - EIGENVALUE	=	4.2518E-04
EXPERIMENTAL BUCKLING	=	0.0
EFFECTIVE MULTIPLICATION FACTOR	=	1.1134E 00

13) BURN-UP

A) LINEAR CHAIN MACROSCOPIC ABSORPTION CROSS SECTIONS

REGION	1	2	3
CHAIN 13	3.9360E-05	4.2596E-05	5.9304E-05
CHAIN 14	1.2617E-05	1.4092E-05	2.1439E-05
CHAIN 15	5.3052E-06	5.8391E-06	8.5460E-06
CHAIN 16	3.8362E-06	4.2665E-06	6.4484E-06
CHAIN 17	2.0639E-05	2.2628E-05	3.2663E-05
CHAIN 18	8.2322E-05	9.1693E-05	1.3894E-04
CHAIN 19	1.7415E-03	1.8671E-03	2.4446E-03
CHAIN 20	7.6213E-04	8.0356E-04	9.9333E-04
CHAIN 21	1.2713E-04	1.4030E-04	1.8918E-04
CHAIN 22	5.6639E-05	6.2147E-05	8.9602E-05
CHAIN 23	6.5828E-06	6.8924E-06	8.2850E-06
CHAIN 24	3.2152E-05	3.5287E-05	5.0983E-05

B) FISSION PRODUCT TOTAL MACROSCOPIC ABSORPTION CROSS SECTIONS

REGION	1	2	3
	2.8847E-03	3.0905E-03	4.0430E-03

C) FISSION PRODUCT TOTAL MACR. ABS. CROSS SECT. IN THE CELL = 3.6919E-03

D) FISSIONS IN THE CELL FOR THE TIME-STEP

ISOTOPS	FISSIONS
233	0.0
235	1.0700E 20
238	7.8490E 18
239	9.1498E 18
241	6.8676E 15
242	0.0

E) TOTAL FISSIONS IN THE CELL = 2.4732E 20

14) ATOMIC DENSITIES FOR THE NEXT TIME-STEP (ATOM PER CM**3)

CHAIN 2 (DEPLETION)

REGION	1	2	3
ISOTOP 2	3.2077E 20	3.1935E 20	3.1329E 20
ISOTOP 11	3.7077E 18	3.9230E 18	4.8448E 18

CHAIN 3 (DEPLETION)

REGION	1	2	3
ISOTOP 3	4.7333E 22	4.7332E 22	4.7328E 22
ISOTOP 12	3.2618E 15	3.4123E 15	4.0618E 15
ISOTOP 13	4.7649E 17	4.9847E 17	5.9333E 17
ISOTOP 4	1.7889E 19	1.8637E 19	2.1778E 19
ISOTOP 14	3.8999E 17	4.2524E 17	6.0003E 17
ISOTOP 5	1.4192E 16	1.5574E 16	2.3982E 16

CHAIN 13 (FISSION PRODUCTS)

REGION	1	2	3
ISOTOP 63	3.7850E 16	4.0105E 16	4.9378E 16
ISOTOP 44	1.2839E 18	1.3595E 18	1.6679E 18
ISOTOP 45	1.4398E 15	2.3353E 15	2.9587E 15
ISOTOP 46	1.1048E 18	1.1701E 18	1.4357E 18
ISOTOP 47	9.3230E 17	9.8551E 17	1.2043E 18
ISOTOP 48	3.0075E 17	3.1728E 17	3.8268E 17
ISOTOP 49	4.3871E 17	4.6222E 17	5.5418E 17
ISOTOP 50	4.4379E 15	4.7351E 15	6.1935E 15
ISOTOP 16	1.6910E 15	1.9558E 15	7.7485E 14

CHAIN 14 (FISSION PRODUCTS)

REGION	1	2	3
ISOTOP 15	4.6507E 15	4.9170E 15	5.9978E 15
ISOTOP 16	2.6893E 17	2.8326E 17	3.3933E 17
ISOTOP 52	0.0	0.0	1.9159E 14
ISOTOP 54	1.0364E 17	1.0882E 17	1.2886E 17
ISOTOP 55	6.5311E 16	6.8474E 16	8.0688E 16
ISOTOP 56	2.5493E 16	2.7165E 16	3.4484E 16

CHAIN 15 (FISSION PRODUCTS)

REGION	1	2	3
ISOTOP 57	1.0783E 16	1.1465E 16	1.4344E 16
ISOTOP 58	1.1809E 17	1.2635E 17	1.5719E 17
ISOTOP 59	1.2957E 18	1.3746E 18	1.7042E 18

CHAIN 16 (FISSION PRODUCTS)

REGION	1	2	3
ISOTOP 60	1.3292E 16	1.4102E 16	1.7471E 16
ISOTOP 61	8.0758E 16	8.5676E 16	1.0611E 17
ISOTOP 62	1.7510E 18	1.8626E 18	2.2840E 18
ISOTOP 36	1.0942E 11	1.1660E 11	1.4361E 11

CHAIN 17 (FISSION PRODUCTS)

REGION	1	2	3
ISOTOP 60	1.3292E 16	1.4102E 16	1.7471E 16
ISOTOP 61	8.0758E 16	8.5676E 16	1.0611E 17
ISOTOP 64	1.3767E 18	1.4589E 18	1.8003E 18
ISOTOP 65	3.4170E 15	3.7670E 15	5.4750E 15

CHAIN 18 (FISSION PRODUCTS)

REGION	1	2	3
ISOTOP 66	1.8124E 16	1.9210E 16	2.3684E 16
ISOTOP 67	1.8738E 17	1.9857E 17	2.4465E 17
ISOTOP 68	1.0651E 18	1.1270E 18	1.3802E 18

CHAIN 19 (FISSION PRODUCTS)

REGION	1	2	3
ISOTOP 31	3.8606E 15	4.0941E 15	5.0609E 15
ISOTOP 36	2.1772E 15	2.2320E 15	2.4056E 15

CHAIN 20 (FISSION PRODUCTS)

REGION	1	2	3
ISOTOP 17	8.4717E 17	8.9719E 17	1.1025E 18
ISOTOP 18	6.6436E 17	7.0444E 17	8.6611E 17
ISOTOP 19	5.9963E 16	6.3498E 16	7.7951E 16
ISOTOP 20	4.3249E 17	4.5734E 17	5.5837E 17
ISOTOP 21	4.7208E 15	4.9042E 15	5.5953E 15
ISOTOP 23	6.3072E 15	6.6808E 15	8.2016E 15
ISOTOP 24	2.9439E 16	2.9795E 16	3.2296E 16
ISOTOP 25	8.8026E 17	8.9984E 17	9.5043E 17
ISOTOP 26	9.3736E 15	9.2888E 15	8.9722E 15
ISOTOP 27	2.5629E 17	2.6302E 17	2.8083E 17
ISOTOP 28	1.0194E 15	1.0787E 15	1.3124E 15
ISOTOP 29	1.7261E 17	1.7561E 17	1.8155E 17
ISOTOP 30	3.9678E 16	4.0209E 16	4.2408E 16
ISOTOP 53	4.4381E 15	4.4696E 15	4.4192E 15

CHAIN 21 (FISSION PRODUCTS)

REGION	1	2	3
ISOTOP 32	1.5229E 17	1.6098E 17	1.9736E 17
ISOTOP 33	1.2814E 15	1.3577E 15	1.6712E 15
ISOTOP 26	6.8359E 16	7.0179E 16	7.6146E 16
ISOTOP 27	3.2247E 16	3.6213E 16	5.3779E 16
ISOTOP 28	2.4624E 13	2.8948E 13	5.1463E 13
ISOTOP 29	4.0452E 14	4.7509E 14	8.5942E 14
ISOTOP 30	5.0661E 12	5.7198E 12	1.4505E 13
ISOTOP 53	1.1955E 11	2.3194E 12	4.7520E 11

CHAIN 22 (FISSION PRODUCTS)

REGION	1	2	3
ISOTOP 17	8.4717E 17	8.9719E 17	1.1025E 18
ISOTOP 18	6.6436E 17	7.0444E 17	8.6611E 17
ISOTOP 19	5.9963E 16	6.3498E 16	7.7951E 16
ISOTOP 20	4.3249E 17	4.5734E 17	5.5837E 17
ISOTOP 22	1.6490E 15	1.7699E 15	2.2910E 15
ISOTOP 23	1.2028E 13	1.3710E 13	2.2311E 13
ISOTOP 24	5.2933E 13	5.7686E 13	7.8062E 13
ISOTOP 25	3.1486E 16	3.3143E 16	3.9128E 16
ISOTOP 26	4.0861E 14	4.1782E 14	4.5526E 14
ISOTOP 27	9.1597E 15	9.7059E 15	1.1707E 16
ISOTOP 28	7.2556E 12	8.0463E 12	1.1603E 13
ISOTOP 29	1.0140E 16	1.0685E 16	1.2750E 16
ISOTOP 30	1.9659E 15	2.0798E 15	2.4983E 15

ISOTOP 53	2.1664E 14	2.2779E 14	2.6889E 14

CHAIN 23 (FISSION PRODUCTS)

REGION	1	2	3
ISOTOP 70	2.0868E 13	2.2087E 13	2.7073E 13
ISOTOP 71	1.6720E 14	1.6432E 14	1.5504E 14

CHAIN 24 (FISSION PRODUCTS)

REGION	1	2	3
ISOTOP 72	2.5985E 19	2.7498E 19	3.3777E 19

FISSION PRODUCT MACROSCOPIC ABSORPTION CROSS SECTIONS

CHAIN 13

REGION	1	2	3
ISOTOP 43	0.0	0.0	0.0
ISOTOP 44	1.0605E-05	1.1605E-05	1.6588E-05
ISOTOP 45	5.3751E-09	9.1454E-09	1.4177E-08
ISOTOP 46	2.8596E-06	3.1004E-06	4.2775E-06
ISOTOP 47	6.0532E-07	6.5443E-07	8.9528E-07
ISOTOP 48	0.0	0.0	0.0
ISOTOP 49	2.5237E-05	2.7174E-05	3.7451E-05
ISOTOP 50	4.1289E-08	4.6238E-08	7.4193E-08
ISOTOP 16	6.6617E-09	7.9516E-09	3.6463E-09

CHAIN 14

REGION	1	2	3
ISOTOP 15	9.7989E-06	1.1020E-05	1.7097E-05
ISOTOP 16	1.0594E-06	1.1516E-06	1.5968E-06
ISOTOP 52	0.0	0.0	3.7330E-10
ISOTOP 54	3.2354E-07	3.5206E-07	4.8966E-07
ISOTOP 55	3.3605E-07	3.6300E-07	4.9307E-07
ISOTOP 56	1.0987E-06	1.2055E-06	1.7616E-06

CHAIN 15

REGION	1	2	3
ISOTOP 57	0.0	0.0	0.0
ISOTOP 58	1.3015E-06	1.4556E-06	2.2451E-06
ISOTOP 59	5.1750E-05	5.6935E-05	8.3215E-05

CHAIN 16

REGION	1	2	3
ISOTOP 60	0.0	0.0	0.0
ISOTOP 61	3.6031E-06	4.0102E-06	6.0826E-06
ISOTOP 62	1.4554E-07	1.5870E-07	2.1981E-07
ISOTOP 36	8.7521E-08	9.7536E-08	1.4593E-07

CHAIN 17

REGION	1	2	3
ISOTOP 60	0.0	0.0	0.0
ISOTOP 61	3.6031E-06	4.0102E-06	6.0826E-06
ISOTOP 64	1.6929E-05	1.8494E-05	2.6359E-05
ISOTOP 65	1.0632E-07	1.2319E-07	2.2967E-07

CHAIN 18

REGION	1	2	3
ISOTOP 66	2.4394E-08	2.7204E-08	4.1455E-08
ISOTOP 67	3.8374E-06	4.2749E-06	6.4982E-06
ISOTOP 68	7.8471E-05	8.7391E-05	1.3240E-04

CHAIN 19

REGION	1	2	3
ISOTOP 31	0.0	0.0	0.0
ISOTOP 36	1.7415E-03	1.8671E-03	2.4446E-03

CHAIN 20

REGION	1	2	3
ISOTOP 17	1.5328E-05	1.6906E-05	2.4845E-05
ISOTOP 18	1.5493E-06	1.7242E-06	2.6308E-06
ISOTOP 19	0.0	0.0	0.0
ISOTOP 20	3.2782E-05	3.5778E-05	5.2660E-05
ISOTOP 21	2.8620E-05	3.1269E-05	4.4955E-05
ISOTOP 23	0.0	0.0	0.0
ISOTOP 24	5.7619E-04	6.0351E-04	7.2562E-04
ISOTOP 25	2.0950E-05	2.2329E-05	2.8309E-05
ISOTOP 26	1.7051E-05	1.8142E-05	2.2808E-05
ISOTOP 27	2.0990E-05	2.2301E-05	2.7919E-05
ISOTOP 28	0.0	0.0	0.0
ISOTOP 29	1.9997E-05	2.1241E-05	2.6485E-05
ISOTOP 30	1.4724E-05	1.5580E-05	1.8988E-05
ISOTOP 53	1.3949E-05	1.4774E-05	1.8039E-05

CHAIN 21

REGION	1	2	3
ISOTOP 32	9.1274E-08	9.8880E-08	1.3648E-07
ISOTOP 33	0.0	0.0	0.0
ISOTOP 26	1.2435E-04	1.3707E-04	1.9356E-04
ISOTOP 27	2.6411E-06	3.0705E-06	5.3464E-06
ISOTOP 28	0.0	0.0	0.0
ISOTOP 29	4.6863E-08	5.7465E-08	1.2538E-07
ISOTOP 30	1.8778E-09	2.2162E-09	6.8138E-09
ISOTOP 53	3.7577E-10	3.0805E-10	1.9398E-09

CHAIN 22

REGION	1	2	3
ISOTOP 17	1.5328E-05	1.6906E-05	2.4845E-05
ISOTOP 18	1.5493E-06	1.7242E-06	2.6308E-06
ISOTOP 19	0.0	0.0	0.0
ISOTOP 20	3.2782E-05	3.5778E-05	5.0660E-05
ISOTOP 22	1.1152E-06	1.2579E-06	2.0104E-06
ISOTOP 23	0.0	0.0	0.0
ISOTOP 24	1.0360E-06	1.1685E-06	1.8697E-06
ISOTOP 25	7.4937E-07	8.2241E-07	1.1654E-06
ISOTOP 26	7.4331E-07	8.1606E-07	1.1573E-06
ISOTOP 27	7.5018E-07	8.2297E-07	1.1638E-06
ISOTOP 28	0.0	0.0	0.0
ISOTOP 29	1.1747E-06	1.2924E-06	1.8600E-06
ISOTOP 30	7.2955E-07	8.0585E-07	1.1716E-06
ISOTOP 53	6.8090E-07	7.5295E-07	1.0976E-06

CHAIN 23

REGION	1	2	3
ISOTOP 70	0.0	0.0	0.0
ISOTOP 71	6.5828E-06	6.8924E-06	8.2850E-06

CHAIN 24

REGION	1	2	3
ISOTOP 72	3.2152E-05	3.5287E-05	5.0983E-05

1) ATOMIC DENSITIES (FUEL) AT THE TIME 9.00000E 06

	FUEL 1	FUEL 2	FUEL 3
235	3.20775E-04	3.1935E-04	3.1329E-04
238	4.7333E-02	4.7332E-02	4.7328E-02
239	1.7889E-05	1.8637E-05	2.1778E-05
240	3.8999E-07	4.2524E-07	6.0003E-07
27	0.0	0.0	0.0
12001	0.0	0.0	0.0
10016	0.0	0.0	0.0
12002	0.0	0.0	0.0

5) CRITICALITY

THERMAL UTILISATION FACTOR	9.5173329E-01
THERMAL FISSION FACTOR	1.2596972E 00
THERMAL MULTIPLICATION FACTOR	1.2084131E 00
RESONANCE ESCAPE PROBABILITY	8.9348006E-01
FAST FISSION FACTOR	1.0371475E 00
INFINITE MULTIPLICATION FACTOR (4-FACTOR FORMULA)	1.1282225E 00
THERMAL DIFFUSION AREA	1.7826714E 02

10) OVER-ALL NEUTRON BALANCE

CONVERSION RATIO	=	7.6875E-01
TOTAL PRODUCTION	=	1.2231E 00
TOTAL ABSORPTION	=	1.0948E 00
INFINITE MULTIPLICATION FACTOR (PRODUCTION/ABSORPTION)	=	1.1171E 00
INFINITE MULTIPLICATION FACTOR (4-FACTOR FORMULA)	=	1.1282E 00
MATERIAL BUCKLING - INIT. GUESS	=	4.7624E-04
MATERIAL BUCKLING - EIGENVALUE	=	4.4234E-04
EXPERIMENTAL BUCKLING	=	0.0
EFFECTIVE MULTIPLICATION FACTOR	=	1.1176E 00

Appendix

Burn-up data specification

The evolution of the fuel isotopic composition and of the cell parameters as a function of time is represented by subdividing the total time during which the fission rate in the cell may be assumed to remain at a given value PU into a finite number NSTEP of time-steps of equal length DELTAT. The time-step length must be chosen in such a way that the change in fuel composition taking place in this interval will not affect substantially the flux spectrum in the various fuel regions.

The variation of the fuel isotopic composition is calculated separately for each spatial region into which the fuel is divided.

The calculation proceeds as follows:

1) The initial composition of the cell and the initial power PU per unit length of channel are defined. The time TIMEP after which a new value of PU will be applied is given and subdivided into NSTEP intervals of length DELTAT.

2) A cell calculation is performed and the new fuel composition at the end of the first time-step is evaluated. If DELTAT is equal to 1, new values of PU, TIMEP, NSTEP, DELTAT must then be supplied. If not, DELTAT cell calculations and fuel composition evaluations will be performed before new values of PU, TIMEP, NSTEP,DELTAT are required. In each of the DELTAT cell calculation, the 39-group spectrum and flux distribution are obtained for the corresponding fuel composition; the reaction rates normalized to the given PU are computed and a fresh set of isotopic concentrations is computed which will serve as input data for the next time-step.

3) This procedure continues till the value of TIMEP becomes equal to TIMET, the time given as input at which the burn-up calculation will be terminated.

Note that, while the fission product concentrations are calculated only once per time-step, N3 sets of heavy fuel isotope concentrations are actually derived at each DELTAT (though only the final set is printed for each DELTAT).

The value of PU may be given in arbitrary units; the conversion factor ALFA expresses the relationship between this arbitrary unit and the number of fissions per second.

The isotopic chains to be considered in the calculations are specified through the input data NUCAT (I) where I stands for the ordinal number of the isotopic chain as shown in Fig. 6. The first three chains refer to the heavy fuel isotopes. The eight following chains (I=4-11) correspond to the simplified scheme of fission product representation while the last 14 chains are those of the detailed representation. It is always possible to neglect one or more of these chains if the contribution of the member isotopes to total poisoning is thought to be small. Note that chain 1 may not yet be used since some of the cross section data is missing in the present library.

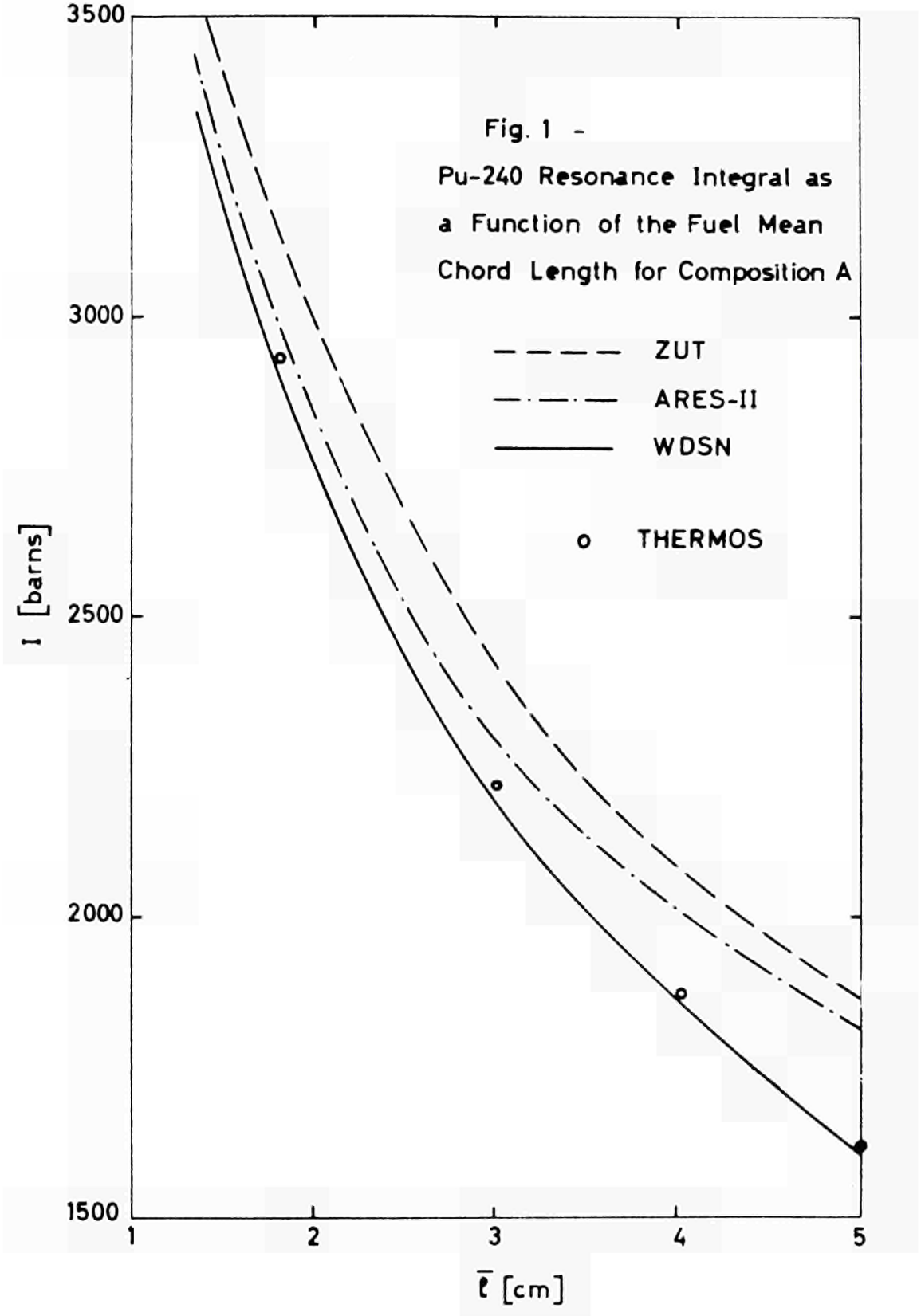


Fig. 1 -
Pu-240 Resonance Integral as a Function of the Fuel Mean Chord Length for Composition A

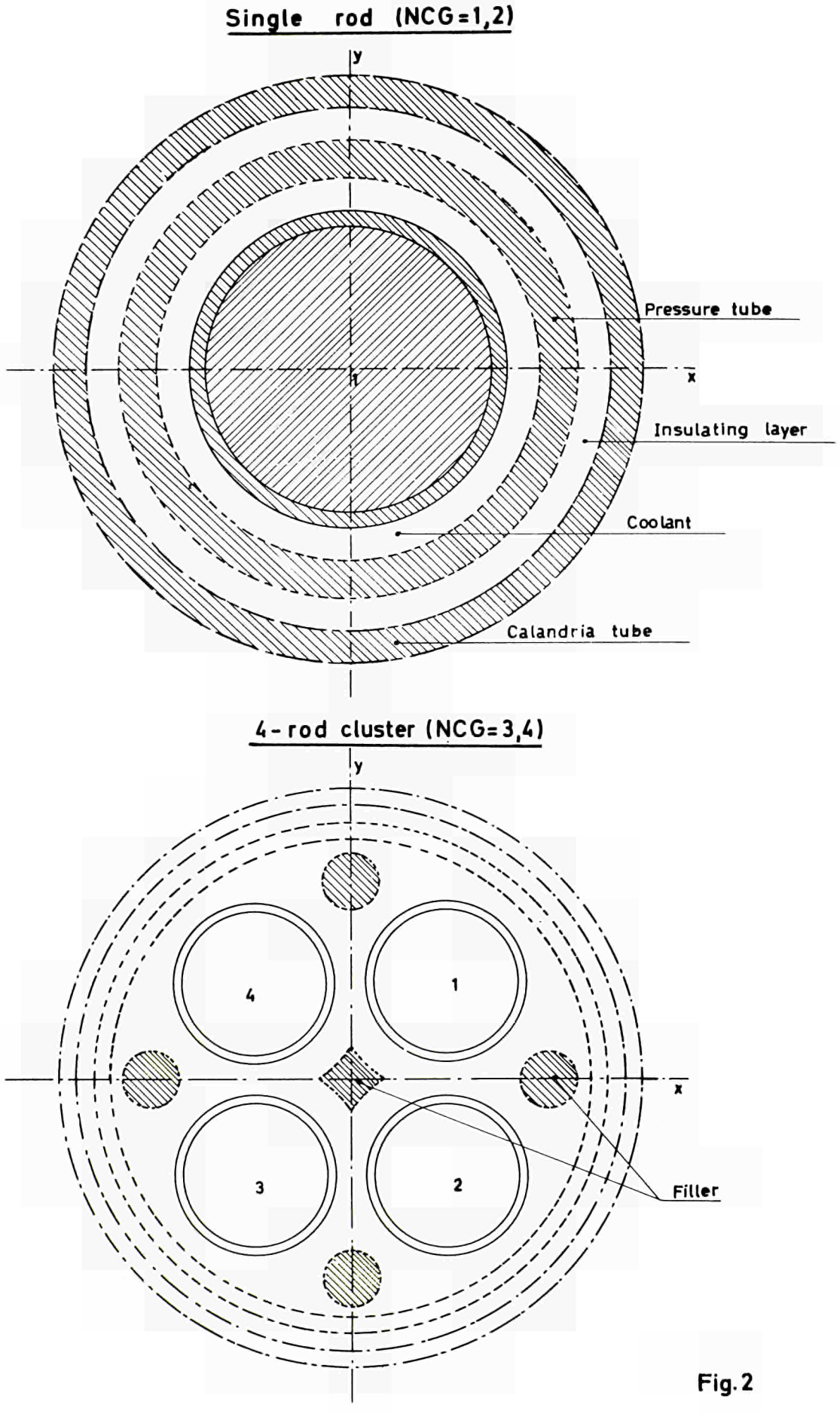
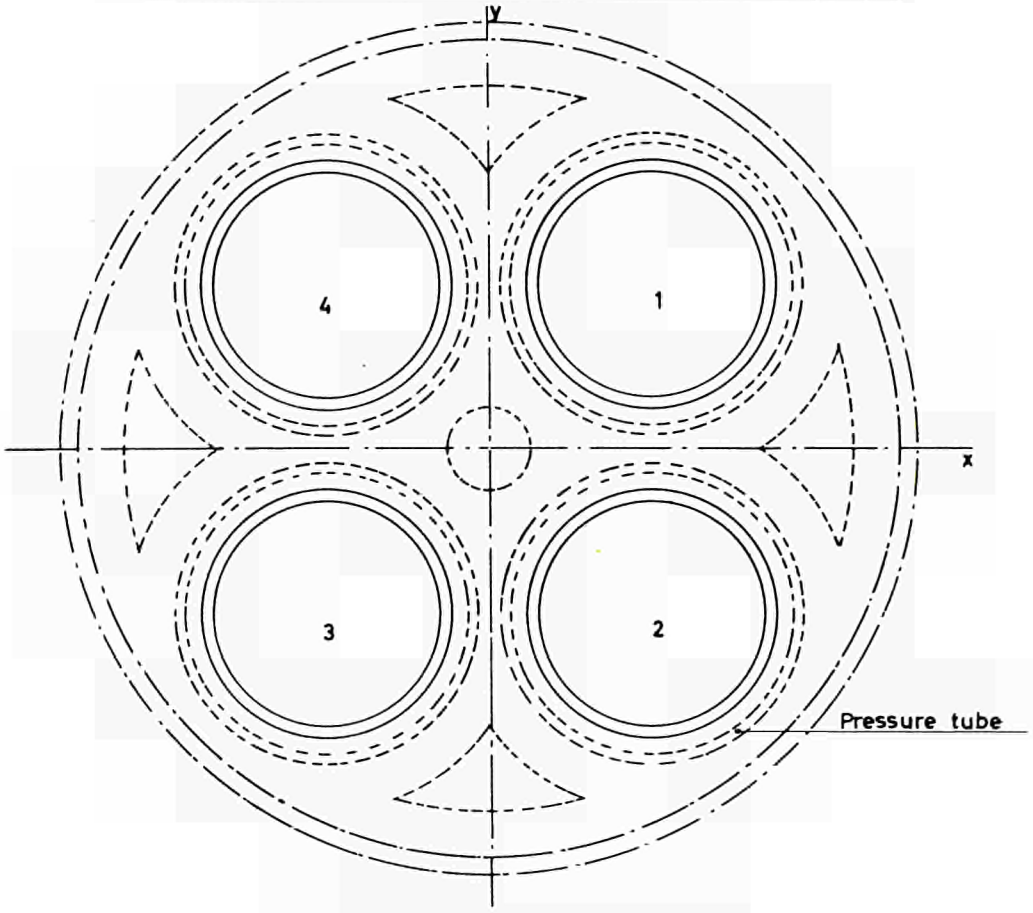

Single rod (NCG=1,2)
y
x
Pressure tube
Insulating layer
Coolant
Calandria tube
4-rod cluster (NCG=3,4)
y
x
4
1
3
2
Filler

Fig. 2

4-rod cluster (pressure tube each pin, NCG=5)



7-rod cluster (NCG=6,7)

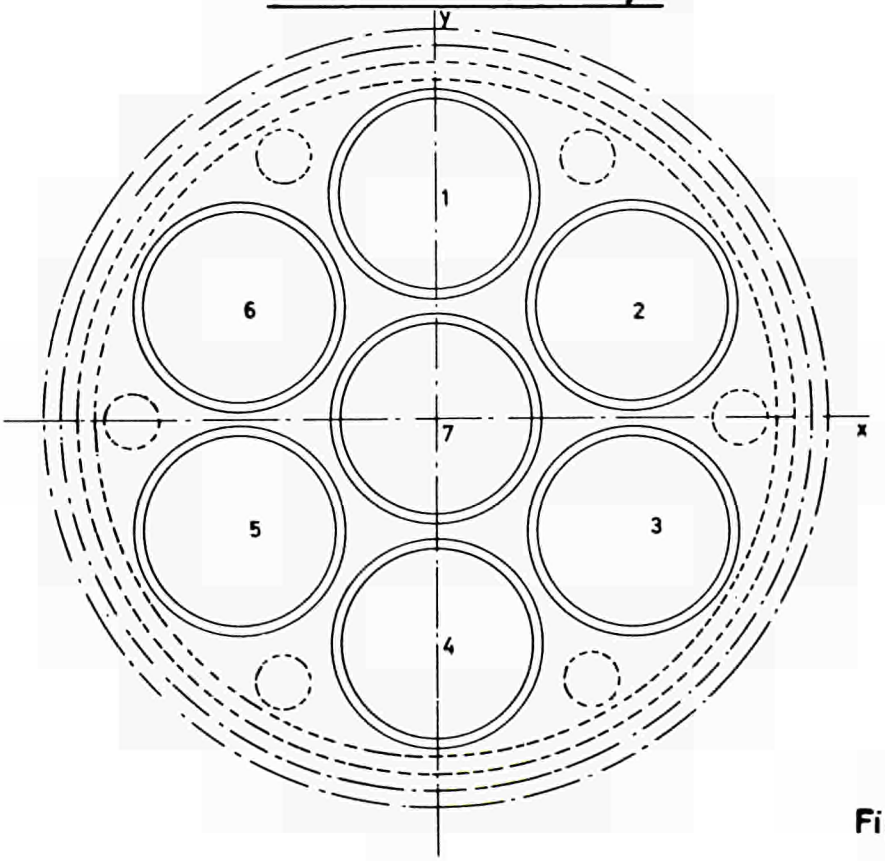
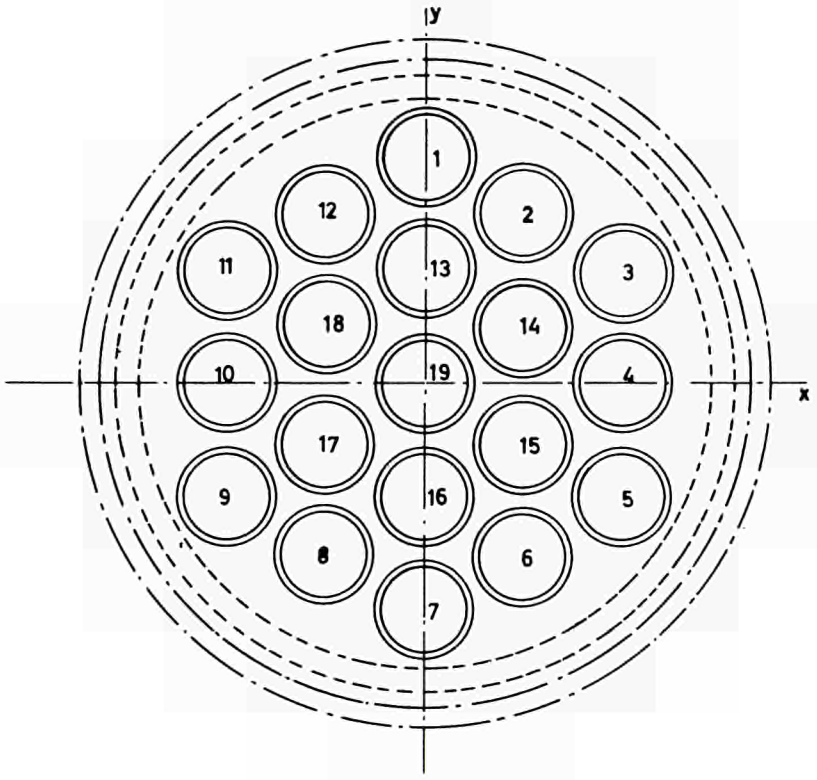


Fig. 3

19-rod hexagonal cluster (NCG=8,10)



19-rod circular cluster (NCG=9,11)

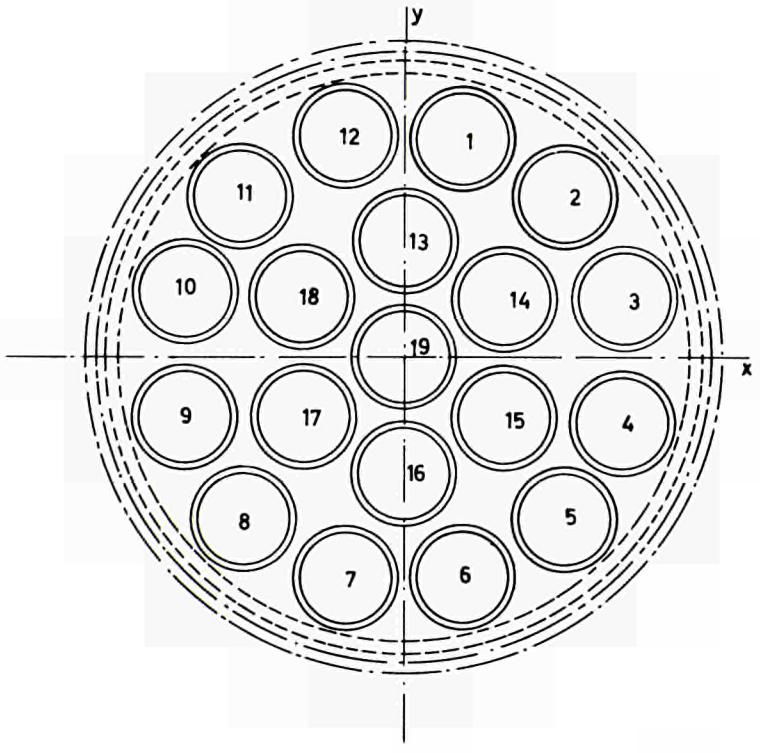


Fig. 4

37-rod cluster (NCG=12,13)

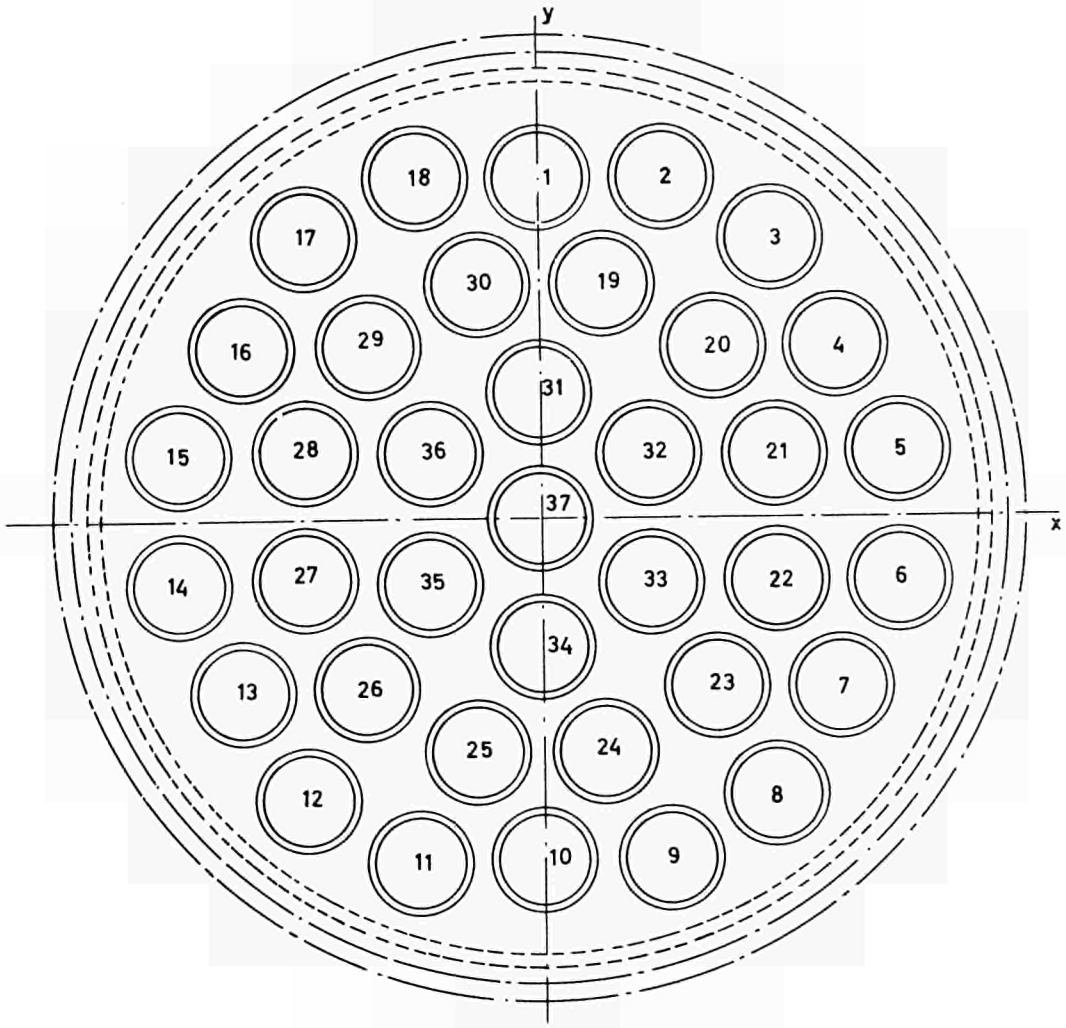
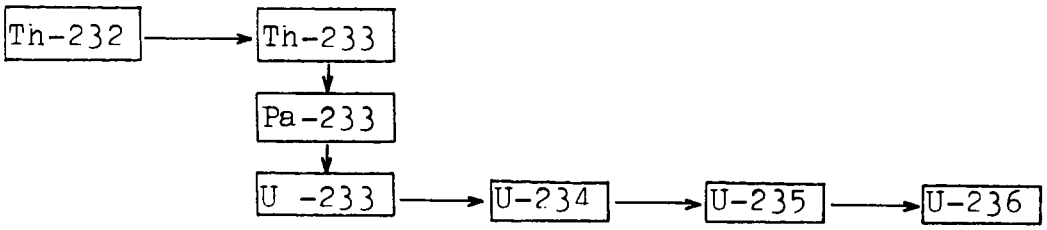


Fig. 5

Figure 6

Chain 1



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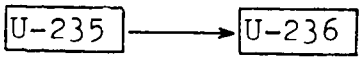

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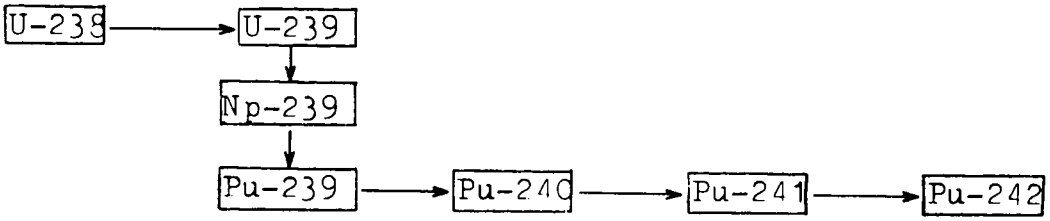

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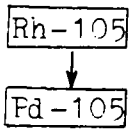
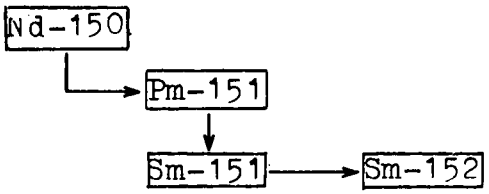


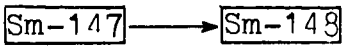
Chain 6



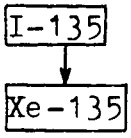
Chain 7

Pseudo fission product (39) Pseudo fission product (40)

Chain 9



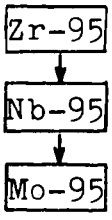
Chain 10



Chain 11

Available for pseudo fission products

Chain 12



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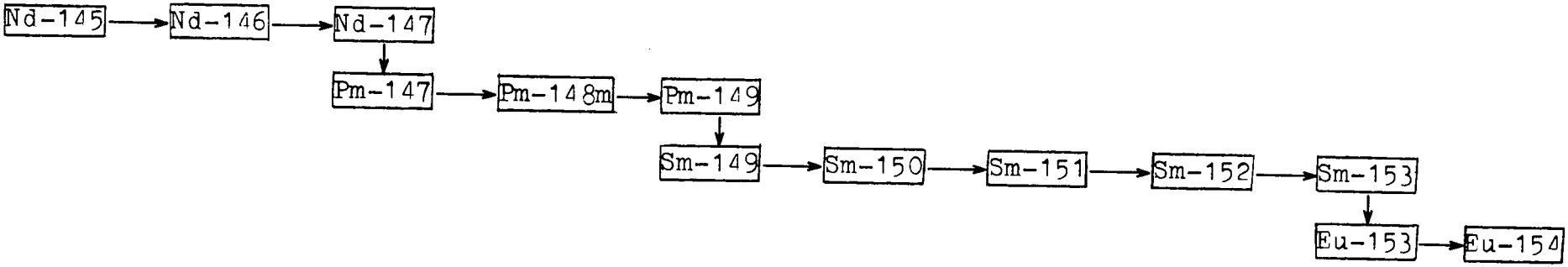
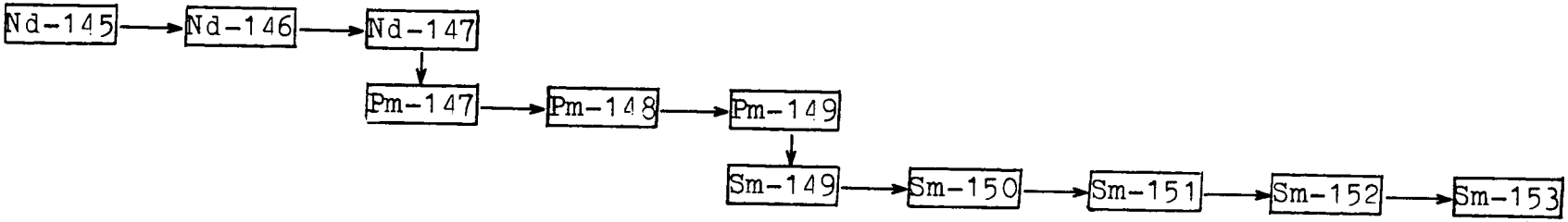
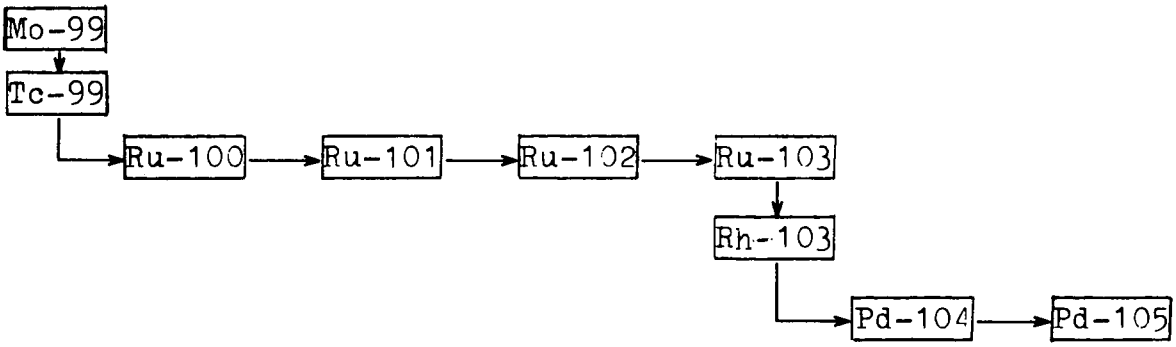


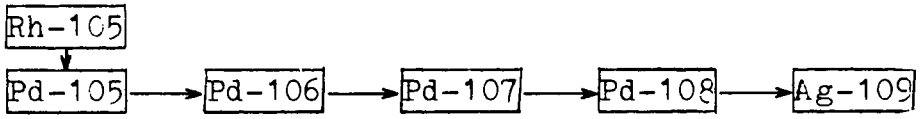
Chain 8



Chain 13



Chain 14



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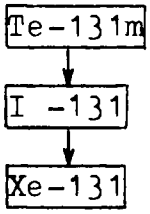

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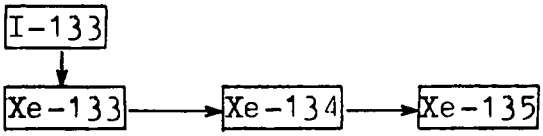

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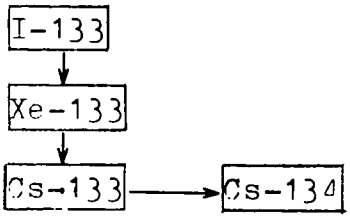

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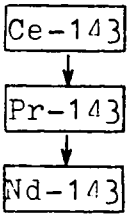

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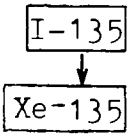

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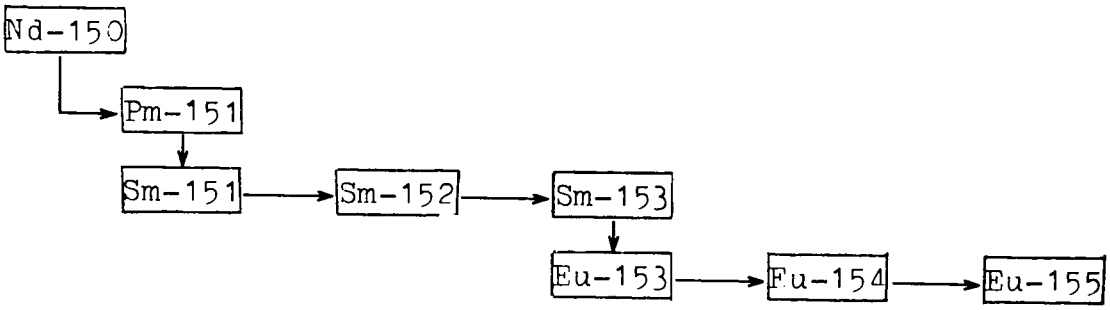

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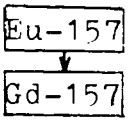

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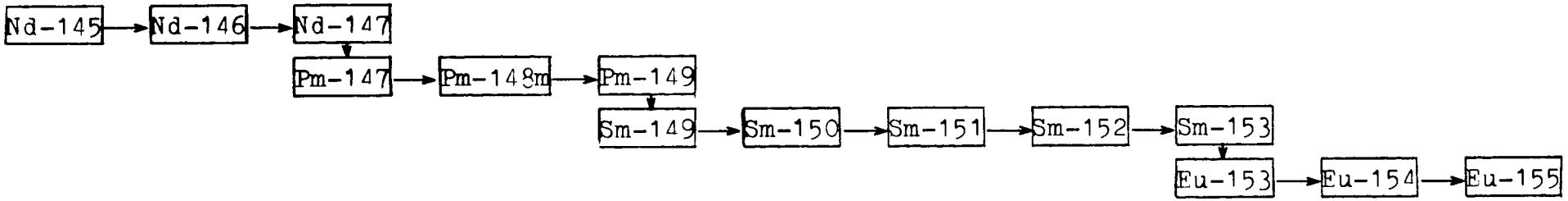

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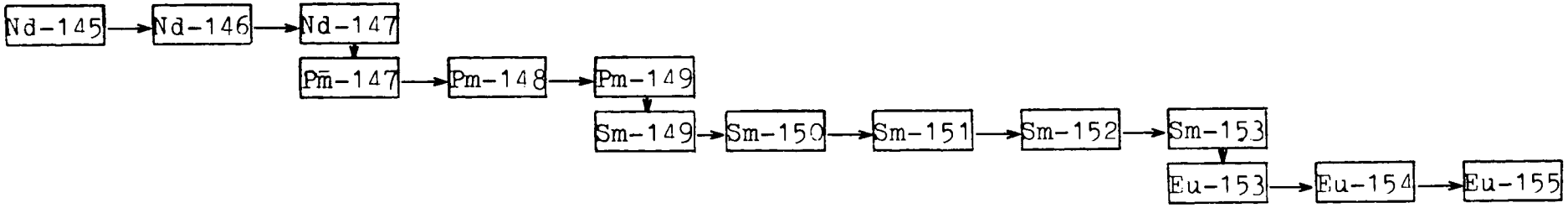

Chain 24

Pseudo fission product (72)

Chain 25

Pseudo fission product (73)

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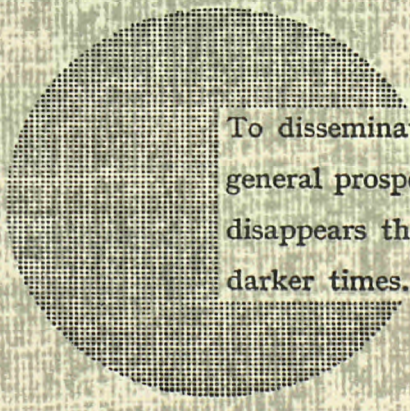

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Alfred Nobel

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